Sustainable and Secure Energy in a Changing Climate:

A US Army Performance Metric

Kristina Tranel
Master of Urban and Regional Planning
May 2015

Table of Contents

Executive Summary

Base realignment and closure (BRAC) is a ticking time bomb for the Army, as the last occurrence was 10 years ago now. BRAC 2005 however left several issues on the table, some Army characteristics were left out or perhaps under-evaluated and undervalued. One of those characteristics is energy use at Army installations. With the changing climate, growing population, and aging infrastructure, there is greater strain on the efficiency and reliability of electricity generation and distribution. Therefore energy security and sustainability have become major concerns for Army installations. Several goals and objectives have been outlined and are being monitored by the Office of the Secretary of Defense. The overarching theme of these energy goals is reducing overall consumption through building improvements and behavioral change and utilizing more renewable energy resources on and off-site.

The Military Value Analysis (MVA) run by the Center for Army Analysis (CAA) did include energy in its environmental elasticity attribute, but its scope was limited to the review of kWh (electricity use) and therms (natural gas). The strength of the environmental elasticity attribute is that it combined water and energy and on base population in order to determine a carrying capacity threshold.

The purpose of this research was to assess the environmental elasticity Military Value Attribute, and to determine what other energy measurements and data sources can or should be included, if any.

Building Efficiency

Energy use intensity, defined as total consumption per square foot per year, is a common metric used to compare similar buildings. However, this is a challenging metric for Army installation comparisons due to considerable variation in size, population, and operations on installations. Instead, the relationship between energy consumption and heating and cooling degree days should be assessed and used to estimate future consumption and costs based on various climate change scenarios. These estimates can then be adjusted to account for installation-specific factors like operations and size as a way of streamlining the process and allowing for a metric that can be applied in different contexts.

Renewable Energy

While reducing greenhouse gas emissions is by itself an important benefit, renewable energy can enhance energy security and reliability, particularly if it is harnessed and used at the installation. The energy infrastructure on base will determine the feasibility of pursuing this strategy and an assessment of renewable energy potential, based on raw resources (solar, wind, and geothermal) should be conducted. It is recommended that an installation's current renewable energy use be evaluated and compared to total energy use to determine how much of an impact renewable energy could potentially make on total demand. Of course this may lead to additional questions such as where does the funding come from and does it comply or compete with the missions and training on base?

Recommendation: Analyze current renewable energy use:

Total Annual Renewable Energy Consumption (on or off-site) (kBTU)

÷

Total Annual Energy Consumption (kBTU) +Potential Renewable Energy (kBTU) / Total Annual BTU

Energy Security

The initial approach taken here was to assess installation level vulnerability based on a spatial and frequency analysis of hurricane and wildfire occurrences interfering with electric transmission lines that power Army installations. This analysis assumed relationships based on visual proximity and therefore could potentially contain errors.

Therefore, further research was done to evaluate electric transmission line connectivity, power capacity and redundancy. Power capacity data was unavailable, and again connectivity was based on assumptions derived from visual and spatial data, when in reality a power line may pass over an Army installation rather than actually connect to it. For these reasons, this alternate approach was determined to be too time intensive for the purposes of CAA, who are seeking a rapid assessment of installations that would take, at most one month.

Introduction

Under the administration of President Obama, the US government has taken the stance that climate change exists and that its effects are already apparent. There is an understanding then, that in the future US cities and rural areas are at risk from more unpredictable and extreme weather events. It will be the job of planners to understand the infrastructural risks associated with climate change and to plan sustainable and resilient regions, cities, and neighborhoods (Birkmann et al., 2010).

Depending on their size and function, US Army bases operate in a manner similar to small cities or university campuses. The training, research, developments and operations on Army bases support national security and therefore, the security and functionality of these bases is crucial for the continuity of the Army, US national defense, and quality of life for civilians.

Climate change threatens the efficiency of infrastructure such as roads, buildings, and utilities such as the transportation of electricity, natural gas, water and wastewater (Ruth & Coelho, 2007). For example, an increase in extremely hot days throughout the year can result in decreased water availability, increased building cooling or electricity consumption, and decreased efficiency of power plants and transmission lines transporting electricity. The threats of climate change however can be mitigated through energy efficient design standards and best management practices in the uses of building materials, and energy efficient technologies (Brown, 2011).

Energy is critical to the Army's ability to perform its missions and operations. Energy is used for mobility (fuel use for air and land vehicles); for weapons; for logistics such as commands, controls, communications, computers, intelligence, surveillance and reconnaissance; and to support human behaviors and quality of life for soldiers and their families and civilian and contracted workers. Decisions about facility energy and benchmarking are typically made at one of three levels: by managers at the installation, by Architectural or Engineering organizations performing design work at the installation, or by higher headquarters (Brown et al, 2013). Decisions at the installation level generally apply to master planning and sustainability planning. For major building renovations, retrofits and other design work, architectural and engineering firms may be contracted and it is within their jurisdiction to make judgement calls based on efficiency and cost-effective practices and materials. At the highest level, energy policies are set by the President, Congress and Army Headquarters.

This report focuses on planning for the maintenance and security of energy at US Army bases by providing benchmarking recommendations that follow broad installation sustainability plans and higher level energy policies. A key aim of this report, is to articulate benchmarking recommendations which can be applied despite differences in the building sizes, mix of uses, population, functions and location of Army installations. Figure 1 shows the processes and specific components developed in this research project.

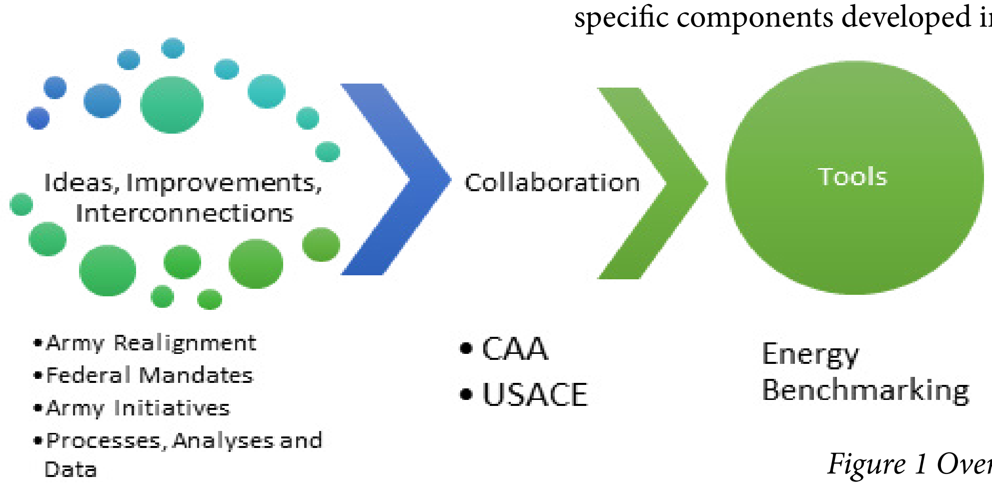

Figure 1 Overview of the Project

Figure 1 depicts the process and components that spurred this research and recommendations for the development of an energy benchmarking tool for the US Army. The project started with several ideas that stem from changes in policies and federal mandates related to energy and climate change that impact Army initiatives. At the same time there were several recommendations for improvements to the realignment analysis methods and data. This evolved into a collaborative partnership between the Center for Army, an Army office that provides analysis and support to strategic Army decision-making, and the US Army Corps of Engineers Construction and Environmental Research Lab (CERL). CAA sought input from energy and environmental engineers and researchers to help in evaluating installation energy trends and security and the USACE relied on CAA to understand previous realignment analyses, requirements and standards. This led to the research and development of a benchmarking tool based on best management practices, current Army energy measurements and inventory, and input from Army and energy experts.

Background

The focus of this research and report is to develop a metric to assure access to sufficient energy supply. Assuring access to sufficient energy supply is described as:

> "Improve and maintain the Army's access to sufficient power and fuel supplies when and where needed. Energy is a critical resource in conducting Army missions. Vulnerabilities to external disruption of power and fuel sources should be minimized and the potential for industry partnerships to enhance energy security and generate net revenues for the Army should be considered."

This definition and its related goals aim to assure access to a sufficient supply of energy for the Army and require an understanding of both environmental (natural disasters), and social threats (targeted attacks on energy infrastructure), as well as knowledge of the reliability and resiliency of the energy supply systems (power lines and gas lines).

The Army is committed to minimizing the impact of possible grid failure, strengthening its fuel management to improve accountability of future purchases and distribution, and expanding on-site renewable and alternative technologies.

Army Strategic Energy Security Goals

The Army Strategic Energy Security Goals (ESGs), as mentioned above, offer ways to improve Army Base energy security. The five goals from the 2009 Army Energy Security Implementation Strategy provide a foundation for the development of an energy attribute with the intent of being integrated into the analyses process for Army Stationing. An attribute is a categorization of a critical Army characteristic used in a formalized Military Value Analysis and is defined as valuable based on input from Army leaders. An attribute defines a framework for measuring and assigning a score on the corresponding characteristic at an installation as well as for comparing and ranking installations against one another. The Military Value Analysis and its attributes were developed as a way to more objectively rank Army installations, however this is based on the subjective set of characteristics that officials consider to be assets to the Army. An example of a Military Value attribute can be found in the appendix of this report. This report documents the review, assessment, and recommendations provided for improvements to energy analysis in stationing.

Client

As the roles and demands of the Army shift over the years, federal leaders call for re-stationing Army bases. Re-stationing generally occurs when the Army has reduced its numbers and operations. The Center for Army Analysis (CAA) is a field operating agency that conducts various analyses to inform senior level Army decisions for current and future national security issues (CAA, 2014) . CAA conducts analysis for strategic positioning, evaluates the Army's ability to mobilize and deploy forces, and conducts resource analysis. The US Army Corps of Engineers is collaborating with the Center for Army Analysis to implement climate change into the analyses that are done specifically for stationing.

The Center for Army Analysis (CAA) is expecting a nationwide re-stationing of Army troops, also known as a base realignment and closure (BRAC). Feedback from the governmental accounting office (GAO) suggested finding a way to more strongly integrate environmental impacts in their analyses based on the GAO's review of CAA BRAC analyses in 2005. Having worked with the US Army Corps of Engineers (USACE) environmental research lab in Champaign, IL before, CAA has partnered with the Corps and asked our team at the research lab to review the metrics for analyses during BRAC 2005 to make recommendations for improvements. Specific adjustments to the environmental impact review were considered, but interfered with other analyses being conducted under the general categories of costs and constraints. Therefore within the four specific Army characteristics assessed—maneuver land, firing ranges, water, and energy—environmental impacts are included in each sector analysis where mitigation of negative environmental impacts are given higher values (positive reinforcement).

Planners constantly face the challenge of defining who planning is done for, which can be analyzed in at least two different dimensions—a specific client or audience and a broader scope affecting diverse groups with unintended consequences. In this case there is a client, but they are their daily lives are the least impacted by the recommendations made in this report. The audience most affected are the public works directors and staff members who may potentially carry out the recommendations made here. Similar to other planning processes, there were several stakeholders involved in the development of these benchmarking recommendations, including but not limited to Army directors of public works, energy managers, and officers under the department of the Secretary of Defense. Additionally, these suggestions will need to be reviewed and approved by senior Army leaders on the installations.

Approach

The scope of work for this project is broad and assumes that another Army base realignment will happen soon and that improvements could be made to the process since its last occurrence in 2005. The role of the US Army Corps of Engineers (USACE) team, consisting of members specializing in maneuver land, noise and firing ranges, deployment, water and energy; is to review and understand the previous assessments performed for the last round of BRAC; research climate change impacts for each sector and integrate future conditions and impacts where possible, make recommendations regarding information that might be missing, data sources that could be used, or different ways of analyzing the characteristics of Army Installations.

It is important to note that the goal of this assessment focused on providing relatively quick and simple methods for collecting and analyzing data and determining the results such that the methods can be repeated in a manner that reduces the learning curve and facilitates a more rapid analysis of Army bases, should realignment recur. The results and recommendations for the energy sector are detailed in this report. The following graphic broadly demonstrates the steps leading to the BRAC decision-making process.

Study Area

A BRAC requires an assessment of all Army bases within the US and as a result, any recommendations, data, and analysis must be applicable to all Army Installations. Seven Army bases were selected based on recommendations from the Center for Army Analysis that capture variation in significant base characteristics like land area, operations and training, regional location, and distribution across US climate zones. The seven sites are: Fort Wainwright, AK; Schofield Barracks, HI; Fort Riley, KS; Fort Bragg, NC; Fort Drum, NY; Fort Bliss, TX; and Joint Base Lewis-McChord, WA.

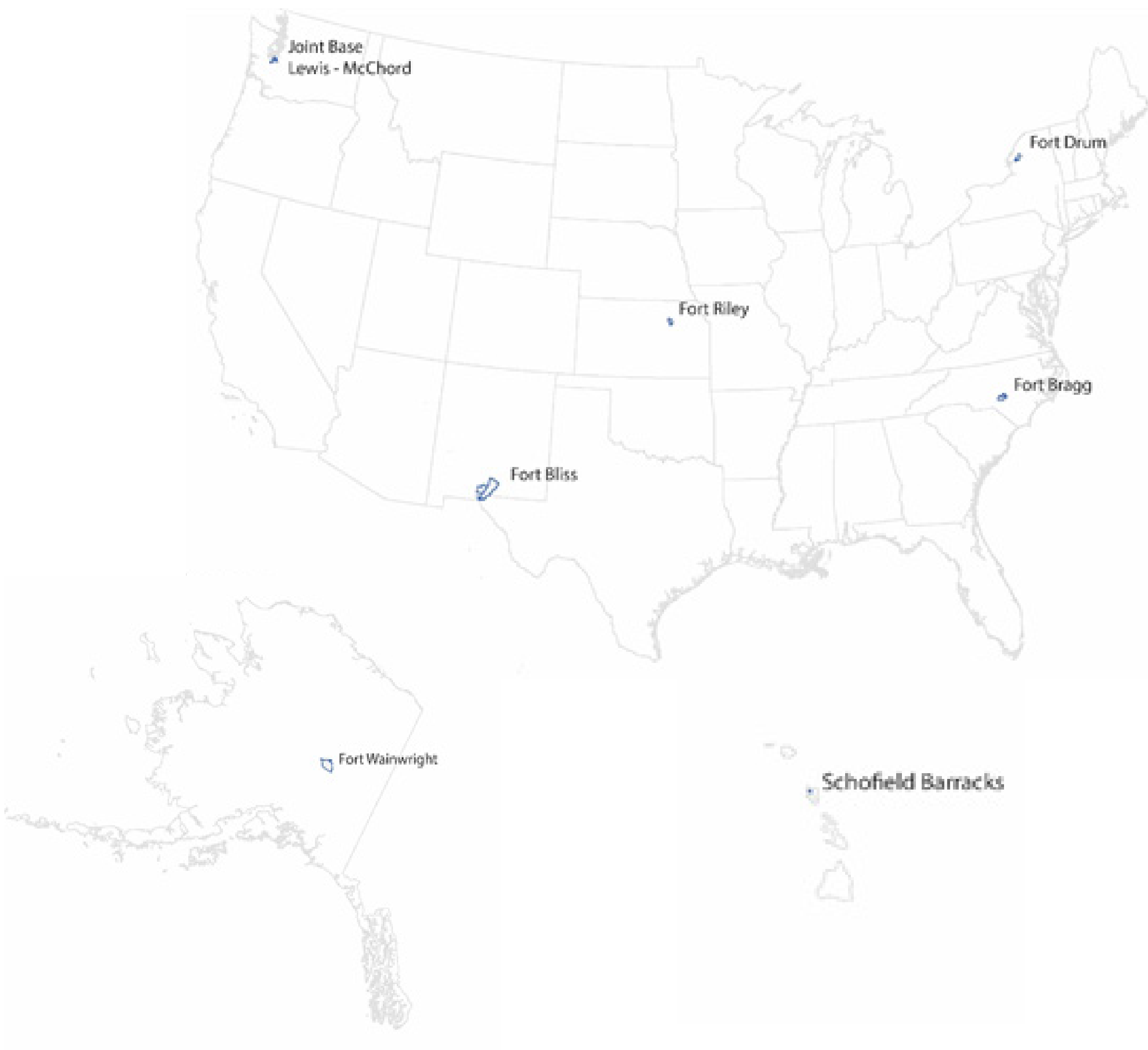

Figure 2 US Army Base Study Sites

The Army and Energy Use: Why Consider Energy In Realignment?

Army Energy Use on Base

Building and facility energy use includes the energy consumed for heating and cooling buildings, hot water, refrigeration, and plug loads that support personal equipment such as soldier weapons, communications, and entertainment (see Figure 3).

While some of these uses can be reduced through energy conservation and building efficiency improvements, access to an energy supply that supports the critical functions of a base must be secured. The energy required to support the critical functions is known as "critical load". The critical load demand must be met at all time and it is recommended that some energy redundancy be made available on the Army base to ensure its continued operations and security.

While some of these uses can be reduced through energy conservation and building efficiency improvements, access to an energy supply that supports the critical functions of a base must be secured. The energy required to support the critical functions is known as "critical load". The critical load demand must be met at all time and it is recommended that some energy redundancy be made available on the Army base to ensure its continued operations and security.

What is Army Stationing?

Army stationing is a reorganization of troops and missions to improve the Army's flexibility and ability to operate. Stationing requires extensive analysis that helps define changes that need to take place within the overall structure and strategic locations of soldiers; operations such as aviation, missile defense, data and cyber capabilities, etc. Stationing often occurs when there are defense strategy changes such as a reduction in total number of soldiers (US DoD, 2013). Stationing recommendations are made by the Center for Army Analysis (CAA) based on three models: military value analysis (MVA), optimal stationing of Army forces (OSAF), and an estimator for cost of base realignment (COBRA). The military value is based on four criteria as shown on the next page.

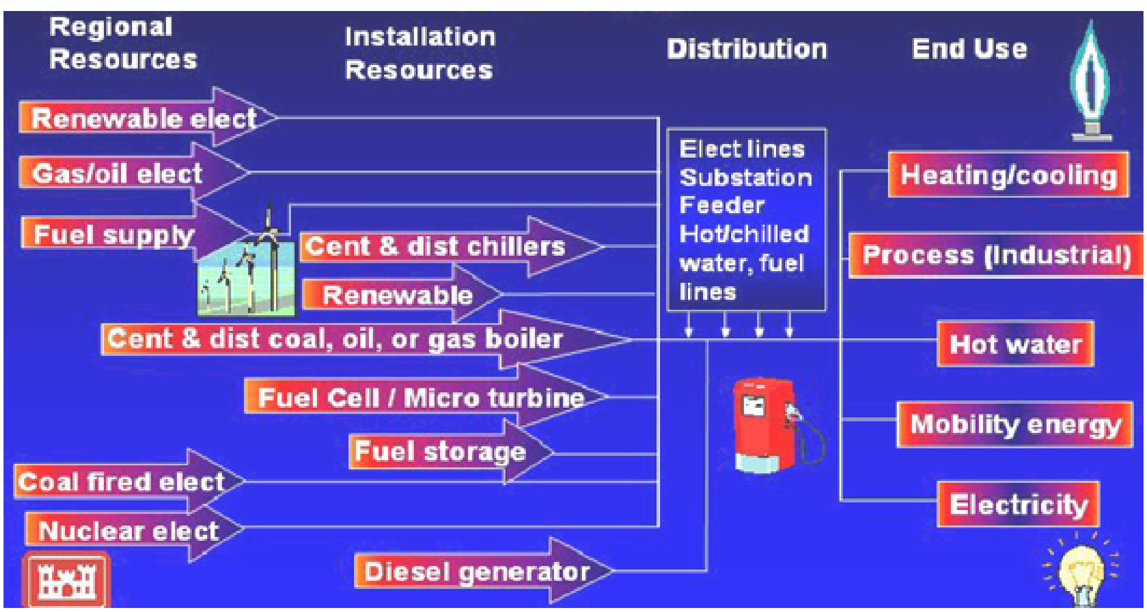

Figure 3 Installation Energy Infrastructure and Uses.
Source: US Army Corps of Engineers

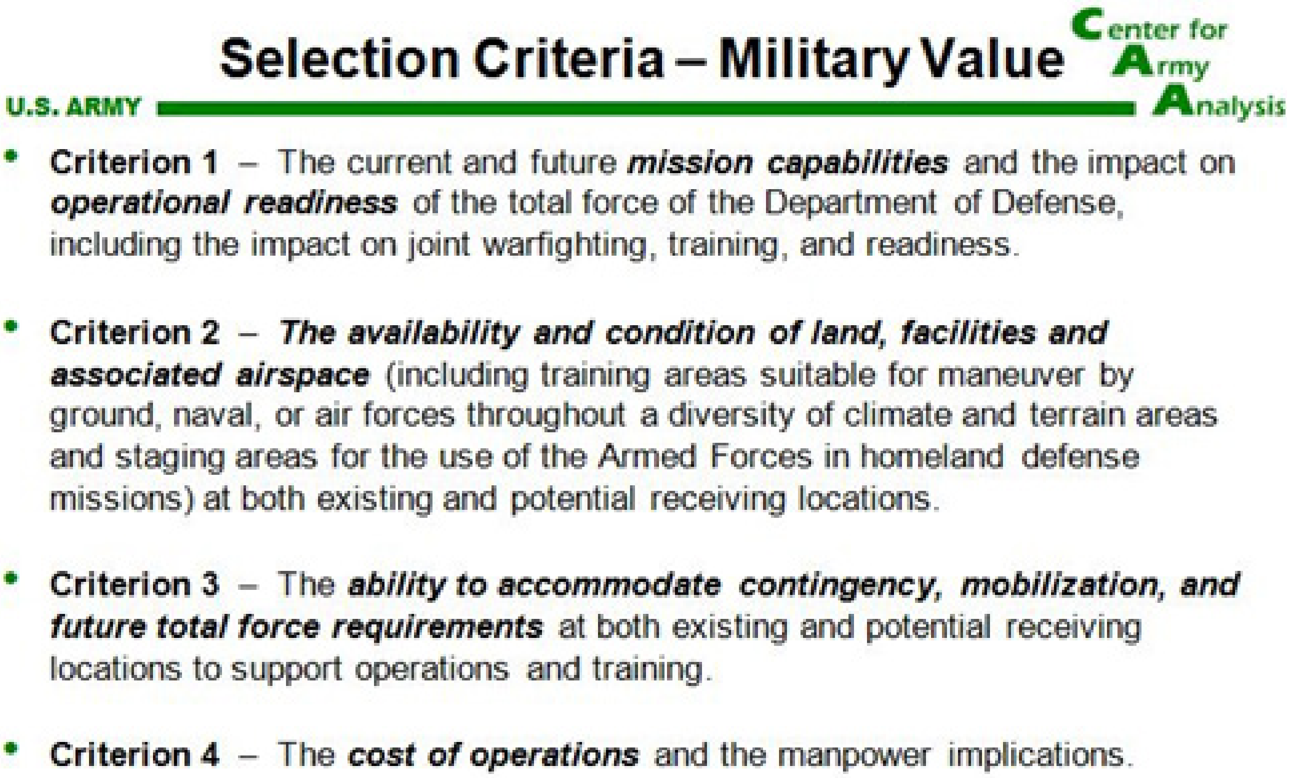

Figure 4 Criteria reguired for determining Military Value. Source: Center for Army Analysis Presentation on Analysis and Tools

The above is a list of the selection criteria for BRAC that emphasizes an installation's ability to serve as a stage for defense missions and to accommodate the needs for additional soldiers (GAO, 2013). Overall, the military value analysis is just one component of the process of recommending base realignment and closure strategies.

Federal Energy Policies and Regulations

The main concerns for the Department of Defense (DoD) regarding energy fall under two main categories: energy conservation and energy security. The most significant policies and directives are listed chronologically in Table 1 and listed in greater detail on the following pages.

Table 1 Summary of Federal Energy Policies

Year	Mandate or Policy	Building Efficiency & Sustainable Design	Emissions Control/ GhG Reductions	Renewable Energy	Energy Metering	Energy Conservation & Consumption Reductions	Access
2005	Energy Policy Act				X		
2005	Federal Leadership in High Performance and Sustainable Buildings	X	X				
2007	Executive Order 13423: Strengthening Federal Environmental Management	X	X		X		
2007	Energy Independence & Security Act	X			X	X	
2007	Unified Facilities Criteria						
2009	Army Energy Security Implementation	X	X	X		X	X
2009	Executive Order 13514: Federal Leadership in Environmental & Economic Performance	X	X		X	X	

These policies, regulations and strategies demonstrate the importance the Department of Defense (DoD) places on energy conservation and security. Therefore these should also be taken into consideration when developing analyses for stationing and evolution of Army operations. For example, increases, decreases or even constant numbers of soldiers, families and civilians will impact energy demand and use on the base. Understanding the available energy, system backups or redundancy, potential for alternative/renewable energies, and weaknesses or vulnerabilities in the infrastructure are important considerations in developing a metric to rank Army base readiness for changes in energy consumption. Factors outside of Army stationing, such as climate change, are also likely to influence changes in energy consumption.

Net Zero Energy Military Installations

Although it is outside the scope of this project, the Net Zero Energy Installation (NZEI) initiative and research applies to the work, data and performance analysis that are being completed in this analysis. For example, the NZEI assessment provides a framework for an installation to develop its energy strategy. Energy considerations and constraints include the following:

Mission Compatibility

The mission compatibility measure emphasizes ensuring that the energy source complies with and meets the needs of the installations. For example it wind turbines located near an airplane runway would be incompatible with the flying mission at many bases, as the turbine blades can interfere with the airplane radar (Booth et al., 2010).

Security

Energy security and reliability can be improved if an installation can meet their critical load demands through on-site renewable energy.

Producing energy on-site improves the

The Energy Policy Act (2005) – requires measuring building energy use and a percentage reduction in building energy use as well as implementing energy efficient products.

Federal Leadership in High Performance and Sustainable Buildings. Memorandum of Understanding (2006) – aims to implement sustainable design to new construction and retrofits. Suggested examples of sustainable design include: enhanced indoor air quality, use of daylighting, use low pollutant emission materials, and reduce the environmental impact of materials by using recycled or bio-based materials.

Executive Order 13423 Strengthening Federal Environmental, Energy, and Transportation Management (2007) – This regulation sets goals relevant for building managers that requires improvement to energy efficiency and greenhouse gas reductions, increasing the use of renewable energy, reducing water consumption intensity, reducing hazardous chemical disposal, and reiterates the Federal Leadership in High Performance and Sustainable Buildings Memorandum.

The Energy Independence and Security Act (2007) – requires increases in the percentage reduction of building energy use, energy and water evaluations every 4 years, using an energy benchmarking system, criteria for selecting green building rating systems, that energy investments that are not major renovations be life cycle cost-effective, require Energy Star label on leased buildings, audits of federal green building performance, and buildings with over a 5,000 square foot footprint are required to have storm water runoff management

Army Energy Security Implementation Strategy (2009) (The Army Senior Energy Council, 2009) established five goals:

(1) Reduce energy consumption:

- reduce the amounts of power and fuel consumed by the Army; focus consumption on critical functions

(2) Increase energy efficiency across platforms and facilities:

- including efficiency improvements in generation, distribution, storage, and end use of electricity and fuel used for system platforms, facilities, units and individual soldiers and civilians.

(3) Increase the use of renewable/alternative energy:
- increase the share of renewable and alternative resources for power and fuel use and consequently decrease dependence on conventional fuel sources.
(4) Assure access to sufficient energy supplies:
- Improve and maintain access to sufficient power and fuel supplies.
- Energy is a critical resource in conducting Army missions.
- Vulnerabilities to disruption of power and fuel sources should be minimized.
- Consider partnerships to enhance energy security and generate net revenues for the Army
(5) Reduce adverse impacts on the environment:
- Reduce emissions from energy and fuel use

Executive Order 13514—Federal Leadership in Environmental, Energy and Economic Performance (2009) – this regulation expands on many of the goals from previous executive orders and in the EISA 2007. This order defines 10 specific goals for federal agencies that include greenhouse gas reduction, water conservation, waste management, implementing sustainable building design and improving local and regional planning.

Unified Facilities Criteria (UFC) 3-400-01 Energy Conservation - establishes a minimum standard for energy conservation in new construction and renovation during planning, design, construction, restoration and modernization phases.

security and reliability, making installations self-sufficient and less threatened or impacted by major blackouts, physical or cyber-attacks, and possible issues occurring in the aging US electrical grid infrastructure and increase in load demands.

Economics

Life-cycle and economic analyses should reflect the improvements in technology, energy availability and costs, distribution, financing options and government incentives, environmental impacts, and costs for operations maintenance and repair or replacement.

Agency Goals and Federal Mandates

Currently, the DoD has a strategic energy plan to reduce consumption, use new technologies, improve awareness and behavior of energy efficiency and conservation and increase renewable energies. Federal mandates focus on energy efficiency and increasing renewable energy, with plans to expand mandates to include carbon emission.

Site Resources

Site resources refers to what is physically available such as siting locations (buildings, land, and accessibility). This will vary among installations, as will climate, renewable energy resources and electrical system connectivity. The assessments suggested from the National Renewable Energy Lab (NREL) above provides a foundation, which the Army can use to establish benchmarks for reaching their net zero energy goal and would also be useful in the event of a realignment such as a BRAC. The net zero strategy recommends first reducing energy consumption in buildings by using energy efficiency improvements, such as controlled lighting for restrooms and classrooms, ventilation controls, and energy and water metering. Once the recommended efficiency improvements are made, the installation determines its energy load and can implement renewable energy to offset that demand.

Previous Army Energy Metrics in Realigment

The only documentation found on energy analysis within BRAC was as a part of an MVA attribute known as environmental elasticity. The environmental elasticity attribute combines the population capacities for the available training land, energy and water consumption, and wastewater and solid waste generated from current populations on base to determine the carrying capacity with these characteristics taken into consideration.

Environmental elasticity is defined as the ability of an installation to economically absorb additional soldiers and civilian employees. It is determined using the following information:

(1) Peak electricity demand and total annual cost
(2) The kW capacity of substations and transmission lines
(3) Peak monthly usage and total annual cost (million cubic feet per day [mcf] and thousands of dollars)
(4) Natural gas pipeline capacity (mcf per day)
(5) Total annual cost of solid waste collection and disposal
(6) Total annual cost of training range maintenance and repair
(7)Peak monthly usage (million gallons) and total annual operational cost of wastewater treatment
(8) Peak monthly use (million gallons) and total annual cost for potable water
(9) Peak monthly use (million gallons) and total annual cost of non-potable water

When energy, water and wastewater capacity is met, the number of soldiers that can be added to an installation is constrained, as there will not be sufficient funds to support the addition of soldiers. Data, such as peak monthly and total annual usage (as outlined above) measures the usage and cost per soldier. This is used to calculate the maximum number of soldiers for each installation. This result is placed into a linear equation to calculate the installation's value and normalized to a scale from 0 to 10. A score of 0 is the minimum representing the lowest degree of elasticity of having no ability to absorb more costs or soldiers. A high score of 10 signifies that an installation has a high degree of elasticity and can support additional soldiers (see Appendix for further information).

The environmental elasticity attribute provides the foundation for assessing water, energy and wastewater accessibility and sustainability. The attribute was not used in the final military value analysis for BRAC 2005, which may be due to political goals at the time and insufficient consideration for cost, infrastructure and environmental impacts (Governmental Accounting Office, 2013). Although it was not used previously, some concepts can still be used to develop and measure energy, such as the evaluation of electricity and natural gas capacity.

Proposed Energy Metric For Army Realignment

Energy Security Attribute

The proposed energy attribute will rank all Army installations on US soil. It will measure the renewable energy potential, electrical grid vulnerability (to extreme weather and power failures), and estimate changes in energy consumption and costs.

Definition

The energy security attribute is an index of current energy consumption and expenses for natural gas, electricity and other significant energy sources (propane gas); renewable energy available in kWh per square foot of compatible space for installing renewable energy technologies; and electrical grid vulnerability based on access to transmission lines and risk of power outages.

Contributing Data

Transmission lines, substations, historic wildfires, historic hurricanes, annual peak demand, annual capacity, cooling degree day (CDD) and heating degree day (HDD) projections, renewable energy potential, Army Energy and Water Reporting System (AEWRS), and data calls or survey questions.

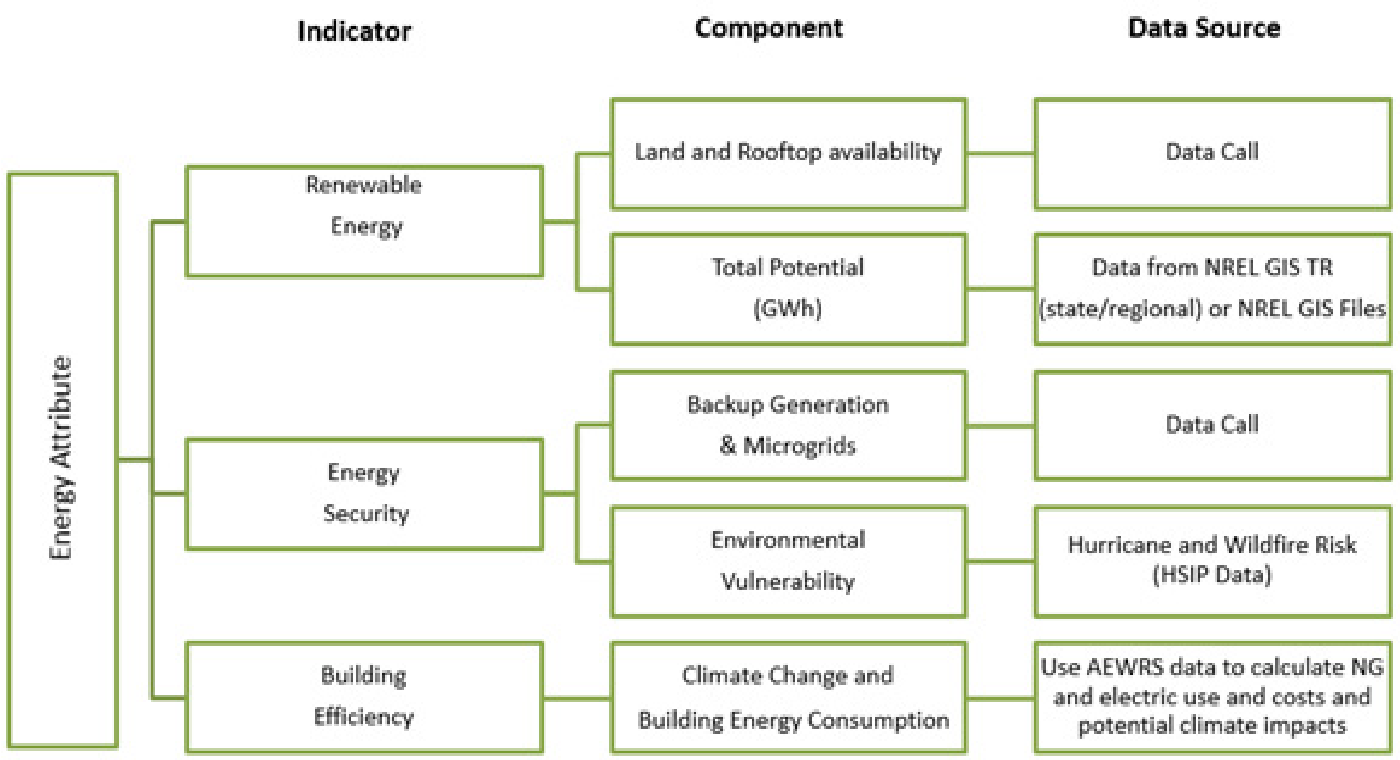

Figure 5 Concept Map of Energy Attribute and Contributing Factors

Figure 5 (above) is a simplified visual representation of all of the factors that inform the overall energy attribute. More detailed information about the three indicators, their components and data sources are described in the following pages.

Renewable Energy

Some of the potential renewable energy resources that can be utilized at Army bases include solar photovoltaics (PV), concentrated solar power, wind, solar hot water, biomass, ground source heat pump and waste-to-energy. Renewable energy is included as part of the energy security attribute because producing energy onsite improves the installation's energy redundancy and reliability.

Data

The data collected and used for the renewable energy component is derived from the Army Energy and Water Reporting System (AEWRS), the Army Installation Status Report for Natural Infrastructure (ISR-NI), the Annual Energy Management Report 2012 (AEMR), and NREL Technical Report (NREL/TP-6A20-51946 [Lopez et al, 2012]).

• AEWRS - A US Army website for tracking utilities information, sustainable design implementation, retrofits, energy and water efficiency improvements, and requires annual updates.

•ISR-NI – Provides similar information as AEWRS, some of this data is linked and downloaded directly from AEWRS, however this link can have several errors, requiring utility, building managers, etc. to review and update. ISR contains reports components of energy such as mission support, sustainability, and environmental quality. These are once again subdivided into energy basics, energy security, and renewable energy.

• The NREL Technical Report analyzes state renewable potential for solar, wind, hydropower, geothermal, biopower technologies. Of those renewable resources, those that are the most feasible for installation at Army bases should be assessed. These include, solar PV, concentrated solar power, and geothermal; given the constraints of cost and missions and operations compatibility.

Methods

The methods for analyzing current and potential energy use onsite are not necessarily straightforward. Several methods were used and compared to one another to determine the most realistic and reasonable results. The first method used data from the

NREL Renewable Energy Data

Solar PV

Solar PV is one of the best methods for the Army to use in terms of facility of installation, cost, and compatibility with base operations. The source for solar PV data is the NREL, which conducted a GIS analysis of several renewable resources within the US. They assessed solar PV potential for both urban and rural geographies. Rural photovoltaics is used for Army base assessment as generally the large, energy intensive and vital training bases are located apart from urban centers. This data is collected by excluding urban areas as defined by the US Census Bureau, and eliminating areas of critical environmental concern. One the total land area is estimated, the potential energy is calculated as a function of:

$$\text{State MWh} = \text{State } \Sigma \text{ (available land) (km}^2) \times \text{power density } (48\ \text{MW/(km}^2)) \times \text{state capacity factor } (\%) \times 8760 \text{ Hours/year}$$

Figure 6 Fort Bliss Solar Photovoltaic Array. Photo Source: Johnson Controls

Concentrated Solar Power
Concentrated solar power is another potential available resource for Army installations. The concentrated solar potential data was taken from the National Solar Radiation Database that reflects satellite-modeled data for direct normal irradiance. The state capacity factors were generated using NREL's System Advisor Model (SAM) and weather data. An equation similar to the solar PV was used to calculate the potential concentrated solar power potential:

$$\text{State MWh} = \text{State} \sum (\text{available land})\ (km\text{^}2\ )\ \text{X power density}\ (32{,}895\ MW/(km\text{^}2\ ))$$
$$\text{X state capacity factor}\ (\%)\ \text{X}\ 8760\ \text{Hours/year}$$

Geothermal Potential
Several Army bases have already installed geothermal or ground source heat pump technologies to offset thermal energy consumption The NREL methods for determining geothermal potential applied known potential electric capacity to temperature-depth data from the Southern Methodist University's Geothermal Laboratory (Booth et al., 2010). The electric generation potential from geothermal sources was calculated from the MW potential at various depths.

Source: Booth et al., 2010

Annual Energy Management Report (AEMR) 2012. Another method used data from NREL and various divisions within the DoD. The results from the NREL data sources are much different from the AEMR. Therefore it is recommended that a data call or survey be designed as a source for renewable energy data. The methods for AEMR and NREL data analysis are described below, followed by recommendations.

Downscaling

The method for downscaling data is straightforward, which is beneficial for a quick assessment and estimate of the potential renewable energy for Army bases. The NREL assessment is based on land area, therefore the methods for determining available capacity on Army installations use the ratio of installation land area to the state land area. The assumptions involved in this method are that the statewide capacity is distributed equally over the land area of the state, which is known to be untrue as landscapes and climates can vary throughout a state. Therefore it is recommended that the results of this analysis be cross-referenced with the relationship between energy use on the installation compared to the energy use for the entire state, as well as the data from the Annual Energy Management Report (AEMR), 2012 (Office of the Deputy Under Secretary of Defense, 2013) which was collected from a DoD survey in 2010.

Table 2 on the next page, shows the estimated renewable energy potential of solar PV, concentrated solar power and geothermal renewable energy sources for the seven case study Army bases. Table 3, to the right, shows the total renewable energy GWh potential compared to the GWh consumed on each base in 2013 (consumption data is from the online AEWRS database).

It appears, according to table 3, that renewable energy could accommodate the annual consumption at each base, under the assumption that the entire land area of the base contains all three renewable energy sources, which is unfeasible. Therefore, two other methods are recommended; the first is a data call for available land area for which renewable energy technologies can be installed, and the second method is to incorporate the survey data from the Annual Energy Management (AEMR) from 2012. Both are discussed further in the following section.

Another method for renewable energy analysis uses data from the AEMR from 2012. An example of the data is shown in the table below for the seven case study installations.

Table 2 Downscaled Data for Renewable Energy Potential at Army Bases

Renewable Energy			Solar PV Potential Estimates		Concentrated Solar Power Potential		Geothermal Potential Estimates		Totals	
Installation	State	Installaton Total Land Area (km2)	Installation GW	Installation (GWh) potential	Installation GW	Installation GWh	Installation GW	Installation GWh	Total GW	Total GWh
Fort Wainwright	AK	3,710	178.08	163,798	0.00	-	NA	NA	178.08	163,798
Schofield Barracks	HI	7	0.34	617	0.25	640	NA	NA	0.59	1,257
Fort Riley	KS	412	19.77	41,183	13.55	37,445	0.24	1,913	33.56	80,540
Fort Bragg	NC	49	2.36	4,260	0.00	-	0.02	149	2.38	4,409
Fort Drum	NY	66	3.15	5,082	0.00	-	0.02	175	3.18	6,071
Fort Bliss	TX	4,400	211.20	403,480	144.73	425,924	2.43	19,150	358.36	5,257
Joint Base Lewis-McChord	WA	1,323	63.48	110,775	43.90	120,330	0.51	4,030	107.89	235,135

Table 3 Renewable Energy Potential vs Onsite Consumption

Renewable Energy			
Installation	Total GW	Total GWh	GWh Consumed in 2013
Fort Wainwright	196.62	215,441.09	1,103.38
Schofield Barracks	0.62	1,367.27	242.48
Fort Riley	35.62	87,270.97	354.496
Fort Bragg	2.68	4,415.36	995.2
Fort Drum	3.51	6,070.98	310.05
Fort Bliss	380.38	912,932.11	453.629
Joint Base Lewis-McChord	114.34	252,147.01	655.29

The data in the table is taken directly from the appendix of the AEMR 2012. There are three categories: Resource Abundance, Mission Compatibility, and Renewable Energy Potential: Estimated Annual Production.

Resource Abundance data is from a Pacific Northwest National Laboratory (PNNL) study that performed a regional analysis of resources (referring to financial resources rather than natural resource for renewable energy) such as regional and state regulations, environmental and financial incentives. The resource abundance is scored in a "stoplight" method where (G)reen is favorable, (A)mber is limited, (R)ed is not favorable and N/A is not evaluated.

Mission Compatibility was part of an Army installation-wide survey. It uses the same stoplight method for suggesting whether that renewable resource would affect the mission capabilities. For the seven case studies, as well as most of the other Army bases, ground source heat pump (GSHP) is the most compatible for the missions, operations and trainings on base. The others are rated as amber, where compatibility with the base operations is limited. The compatibility score was designated by public works managers.

Renewable Energy Potential was also part of the Army installation-wide survey, also completed by the public works managers/department. The renewable energy potential is an estimated measure of potential energy that can be generated by each source. The original data was provided in million BTUs (MMBtu), however in the table &&&below it has been converted to GWh to match previous assessments.

Table 5 on the next page is an example of the results from a 2011 survey of Army (other branches of the military were also included) installations. In table 4 below he numbers provided from the survey in the AEMR report seem a more reasonable estimate.

Recommended Methods

Form data call questions for renewable energy: (1) Survey question: Please indicate the total land area (in square km) of available and compatible space and specify preferred renewable energy resource type (i.e. solar PV, concentrated solar power, or ground source heat pump).

Calculate the percentage of renewable energy consumed compared to total energy consumed. Use the data from the Annual Energy Management Report (AEMR) to calculate the percentage of potential renewable energy on an installation.

Table 4 Calculated Comparison of Renewable Energy Potential vs Actual Consumption. Data from AEMR 2012

Installation		Potential vs Consumption		
		Total GWh	Consumed	%
Fort Wainwright	AK	7.99	1,103.38	1%
Schofield Barracks	HI	0.51	242.48	0.21%
Fort Riley	KS	8.62	354.50	2%
Fort Bragg	NC	40.24	995.20	4%
Fort Drum	NY	203.35	310.05	66%
Fort Bliss	TX	93.84	453.63	21%
Joint Base Lewis-McChord	WA	78.02	655.29	12%

Table 5 Survey Data from the 2012 Annual Energy Management Report

		Resource Abundance					Mission Compatibility					Renewable Energy Potential: Estimatd Annual Production (GWh)				
Installation	State	Solar	Wind	Biomass	Geothermal	GSHP	Solar	Wind	Biomass	Geothermal	GSHP	Solar	Wind	Biomass	Geothermal	GSHP
Fort Wainwright	AK	G	R	A	G	N/A	A	A	A	A	G	1.84		1.28		4.87
Schofield Barracks	HI	R	G	G	R	N/A	A	A	A	A	G		0.51			
Fort Riley	KS	R	A	R	A	N/A	A	A	A	A	G		6.09			2.53
Fort Bragg	NC	A	A	G	R	N/A	A	A	A	A	G	32.38	3.39	4.48		
Fort Drum	NY	A	A	R	R	N/A	A	A	A	A	G	61.59	141.76			
Fort Bliss	TX	A	G	A	G	N/A	A	A	A	A	G	12.53	67.72		10.16	3.43
Joint Base Lewis-McChord	WA	G	A	G	G	N/A	A	A	A	A	G		33.86	7.99	22.38	13.78

Energy Security

Energy security broadly means having reliable access to energy resources that sufficiently meets the highest demand (peak demand). Reliability can be improved by adding redundant power sources and infrastructure such as renewable energy, backup generators, and a microgrid connected to critical buildings and operations. Energy security can be evaluated by assessing the energy mix for the installation compared to the regional energy mix. If the region has a more diverse mix of primary energy resources, then it is less vulnerable to negative impacts such as extremely hot, cold or severe weather. Furthermore, electric grid connectivity evaluations can provide a sense of grid reliability and capacity to provide electricity to an installation.

High-level technical analyses can assess grid connectivity, GIS analysis was performed in a previous assessment, the process and results, however, were subject to several assumptions and correlational relationships. The process assessed the spatial relationship between electricity transmission lines powering Army installations and wildfire and hurricane events. The results of the analysis give a measure of vulnerability by calculating the number of transmission lines affected by these hazards compared to the total number of transmission lines powering installations. The results can be found in section 2 of the Appendix.

For the purposes of Army realignment, the best method for collecting information is through surveys. There is currently one database that supports the evaluation of energy security on installations; the Installation Status Report for Natural Infrastructure (ISR-NI).

Data

Existing data is found in the Installation Status report. The "resource subcategory" known as energy security. This database provides a stoplight ranking system for each subcategory, however a more quantitative system is required to develop an energy metric for realignment. Despite this discrepancy, information from the ISR-NI can still be used to assess energy security. Examples of useful survey questions include the following:

- What is the maximum electrical demand compared to the system capacity?
- What is the maximum natural gas daily usage compared to the maximum infrastructure capacity?
- What is the percentage of vehicle fuel storage required compared to the fuel storage available on the installation to meet mission requirements.
- What percentage of total base energy consumption did onsite production meet last year?
- On how many days within the last year did involuntary interruptions (blackouts, brownouts, anything longer than 2 hours) occur?
- Does the installation have any issues regarding fuel storage capacity that negatively impacts the installation's ability to meet current mission requirements? If yes, provide a detailed comment.

Recommended Methods

- Calculate the percentage of on-site renewable energy as a comparison to total energy consumption.
- Calculate the percentage of on-site electricity demand compared to the system capacity.
- Calculate the percentage of natural gas at peak demand compared to the system capacity.
- Calculate the percent of vehicle fuel storage available compared to the vehicle fuel storage required to meet mission requirements.

A simple summation of the percentages would provide a comparison for all installations. This method is not time consuming, it uses previously gathered data. The public works director for the installation can calculate the percentage for each question, add the data and submit. It is predicted that this method could be used and completed within one month for all continental US Army bases.

Building Efficiency

Building efficiency is an important component in sustainable energy use (Johnson Controls, 2015). Improving the efficiency of energy use and building performance is among the first characteristics that should be examined as it is a "low hanging fruit" to reduce consumption and cost. Building efficiency encompasses a mix of several building types, uses and design materials. Therefore the best measure will only be able to provide a general idea of the efficiency of energy use.

One way to measure building efficiency is to determine the energy use intensity (EUI) or the total energy consumed per square foot of building space, within one year. One challenge of this approach is the different sizes (square footage), building uses and climate zones that characterize Army installations. To make this method more justifiable, installations could be divided into two or three separate categories depending on function and size.

Data

The data used to calculate energy use intensity is from the Army Energy and Water Reporting System (AEWRS), a database that contains utility and building square footage data for all Army installations. This information is updated quarterly (four times a year).

Recommended Methods

The recommended methods are to categorize Army installations into groups based on size and function; for example: small, medium and large bases with large data centers and research versus those that are more outdoor weapons training. Alternately, the installations could be categorized according to building makeup, for example high percentage of barracks (residential) and a low percentage of office, academic, or retail (commercial) buildings, versus other building mixes.

Next sum the total energy consumption for the year and divide the total building square footage by the total annual energy consumption to determine the EUI.

Results

The results a basic EUI calculation are shown below for the seven case study installations, without categorizing the installations based on building size or mix.

Fort Wainwright, located in Alaska unsurprisingly has the highest EUI (556 mBTU/ksf) of the seven case studies. This is unsurprising given its location in a subarctic climate. Meanwhile Schofield Barracks had the lowest calculated EUI of 57 mBTU/ksf. It is interesting to note that Fort Bragg has significant GWH usage, but a more average EUI. Fort Bragg also contains the highest square footage of building space, therefore it is expected to have higher energy consumption.

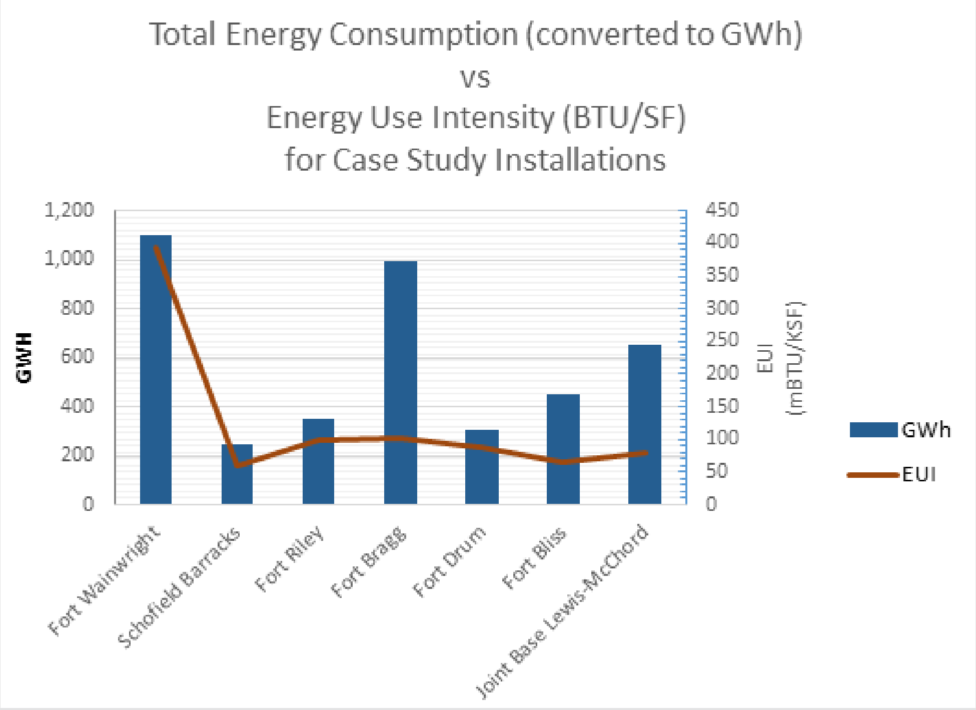

Figure 7 2013 Energy Consumption and EUI for Case Study Installations

Contextual Factors

Energy Trends

Although the goal of this research is to evaluate data and analysis methods for energy benchmarking that is equal across the nation, it is important to provide contextual information to understand any discrepencies or outstanding results. Therefore it is recommended that installations' energy use be understood by looking at ten-year consumption and cost trends, as well as more recent consumption and climate trends. The following is an example of understanding energy trends to provide context and understanding of improvements or reductions in energy efficiency.

Fort Bliss Case Study

In the Southwest Region of the US as defined in the Global Change Impacts in the United States 10-Year Trends:

- Electricity: Linear increase in consumption (R^2 = 0.969) and overall increase in costs
- Natural Gas: relatively steady consumption, between 500,000 and 800,000 kcf
- Propane Gas: sees fluctuations from year to year (and month to month). Makes up 1-2% of total energy used on-site.

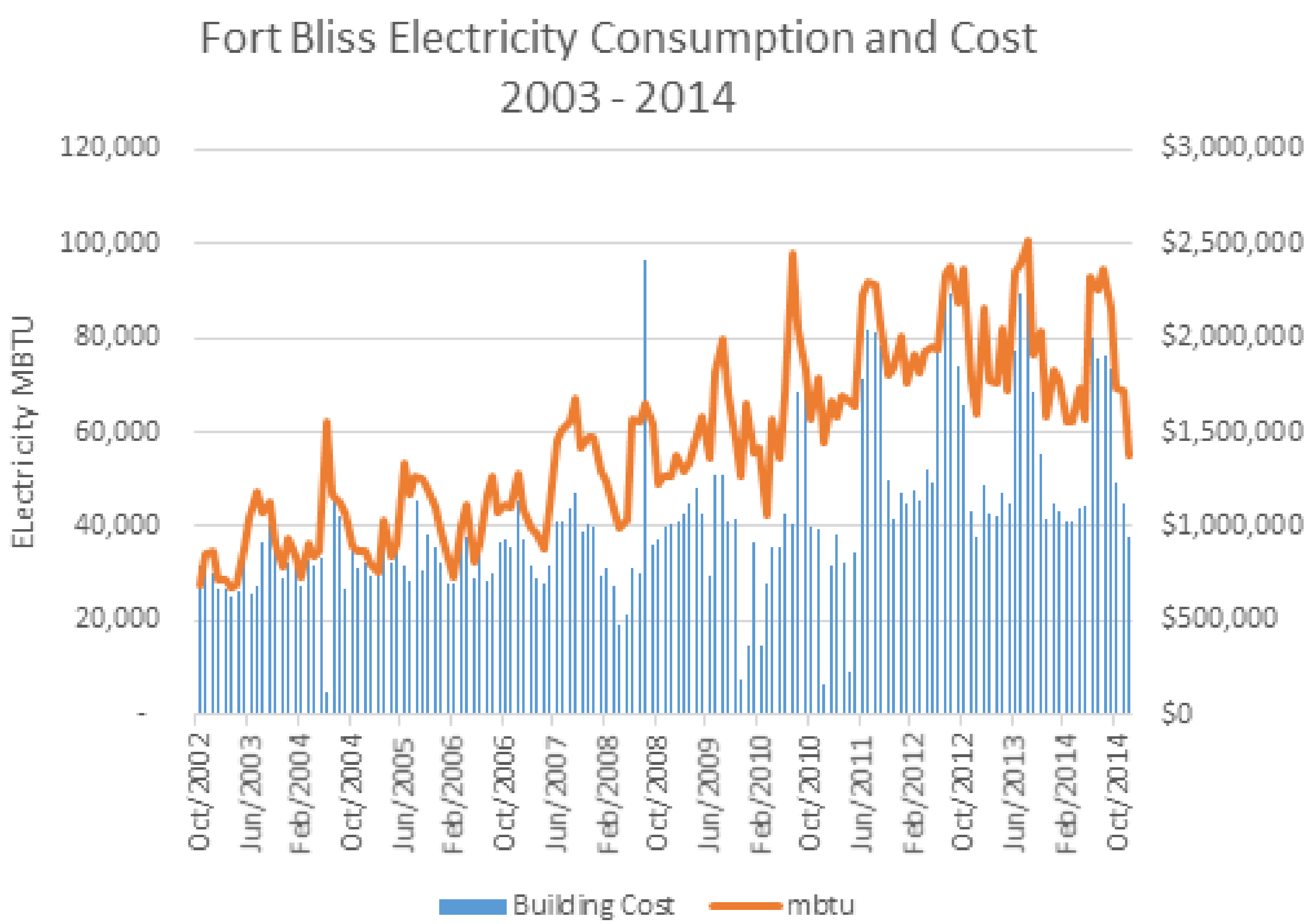

Figure 8 Fort Bliss Electricity Cosnsumption and Cost

Long Term Trends

Fort Bliss has seen an increasing trend in electricity consumption over the past ten years. The total electricity consumption at Fort Bliss increased by 105% from 35,843 MBTU to 73,619 MBTU. This is due to the increase in total square footage on base. For example, the total square footage of building space in 2003 was 11,566 thousand square (ksf). The total square footage increased 90% to 22,014 in 2014. The average annual temperature increased by 0.9°F from 2003 and 2014, and the cooling degree days increased by 1%.

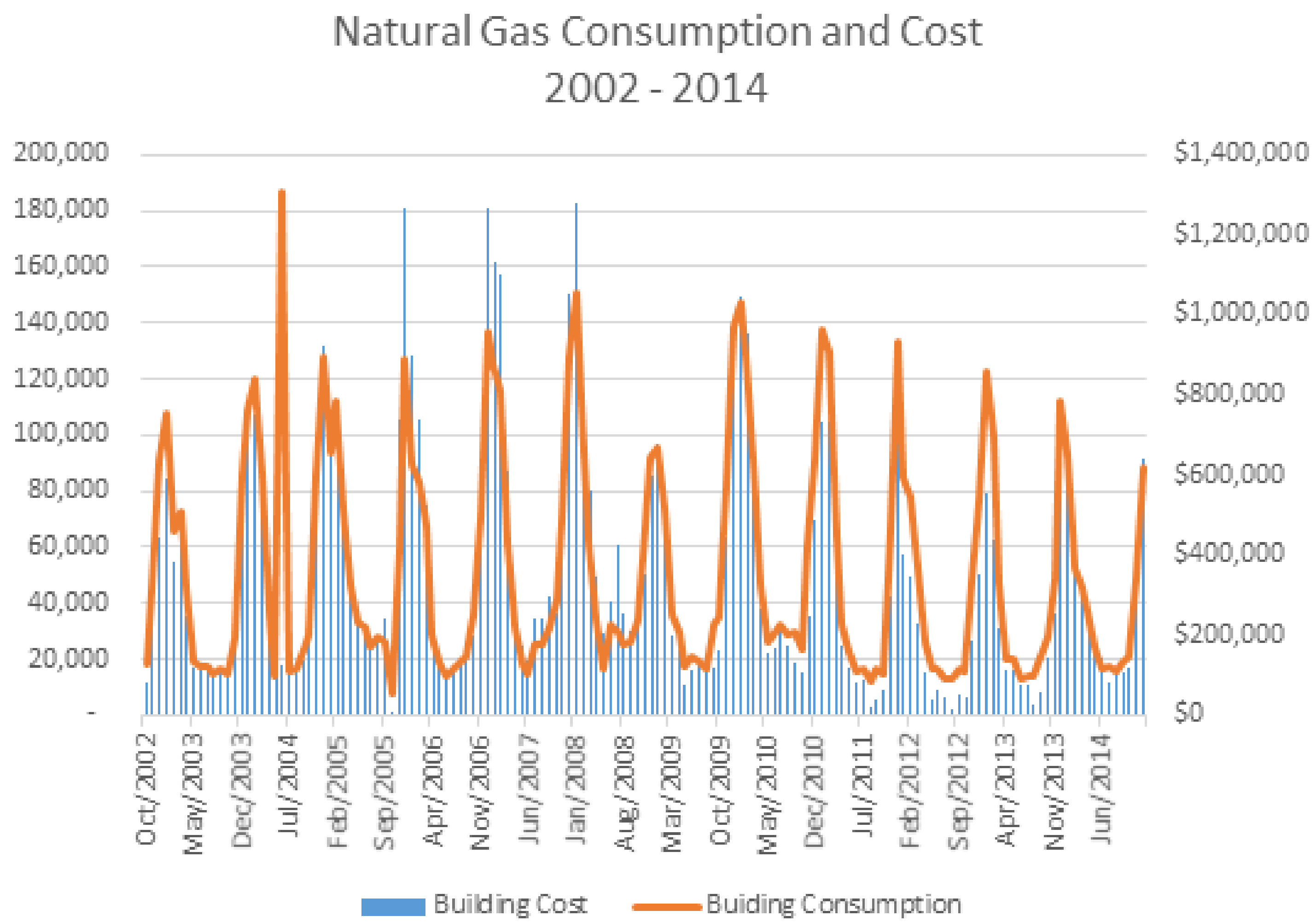

Figure 9 Fort Bliss Natural Gas Consumption and Cost

The trends in these graphs show an increase of total building electricity consumption and significant peaks in cost during the summer months. The natural gas usage appears to have increased from 2005 – 2008 but has more recently returned to the 2003 baseline. According to the US Army Energy and Water Reporting System (AEWRS), Fort Bliss has reduced its energy use intensity (defined as energy use per square foot) by 27 MBTU/KSF (thousand British thermal units per thousand square feet). The greatest difference for the lowest and highest consumption from 2003 to 2014 is around 30,000 MBTU. The annual average natural gas consumption decreased by 6%, at the same time heating degree days decreased by 19% and, as noted above, the temperature increased by 0.9°F. So although the total building stock increased by 90%, the natural gas consumption stayed relatively the same, which could be due to the increasing temperatures and decreasing demand for heating fuel.

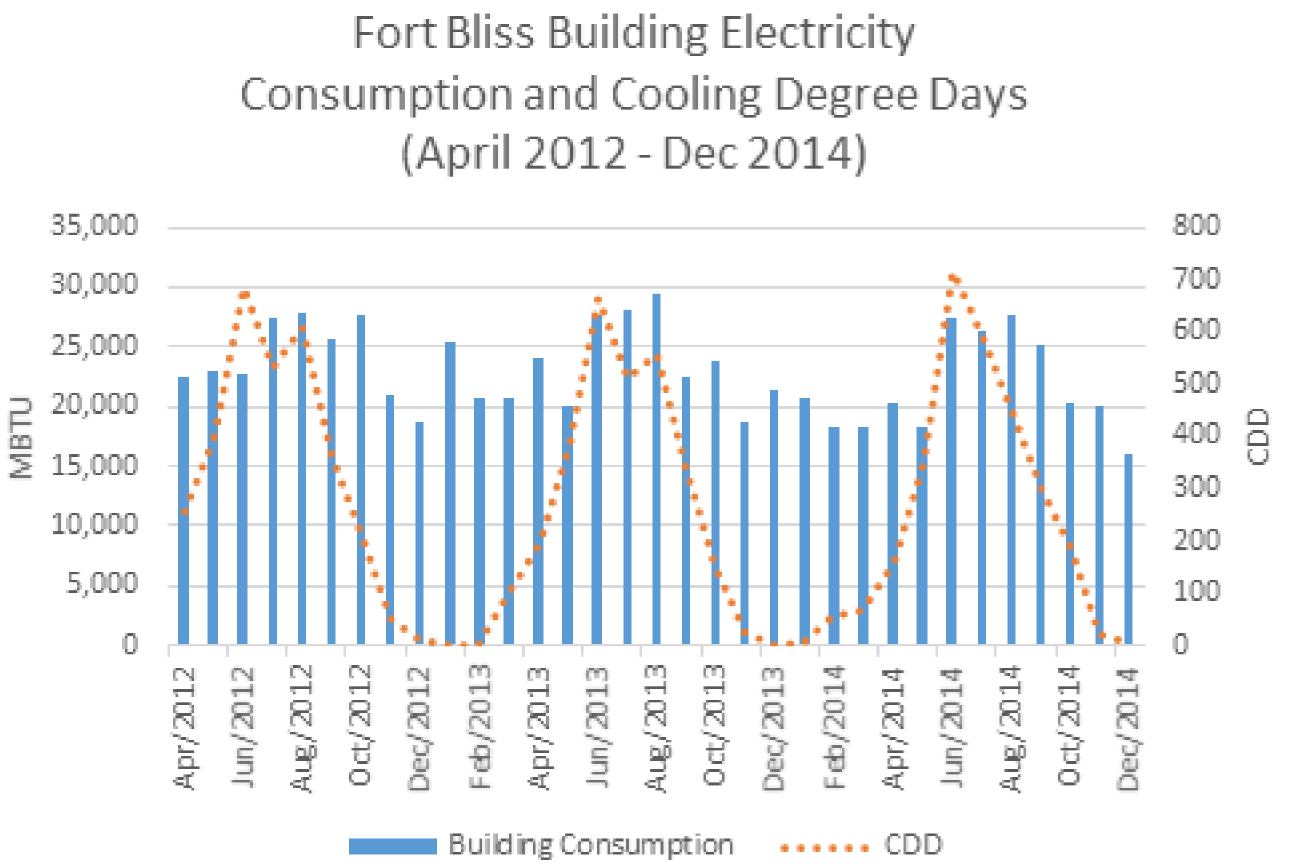

Figure 10 Fort Bliss Electricity Consumption and CDD

Recent Trends

Over the past ten years Fort Bliss has seen an increasing trend in energy consumption, which can be accounted for by the increase in square footage as noted earlier. This graph shows the relationship between cooling degree days and electricity use. The peak CDD and peak energy consumption match supporting the assumption that electricity consumption is the highest on the warmest days. This graph also gives a general indication to the critical load consumption (between 15 and 20 thousand MBTUs) levels for powering data servers, plug loads, lighting, etc. The correlation coefficient of building energy consumption to cooling degree days is 0.71, the critical base load likely reduces the value of the coefficient.

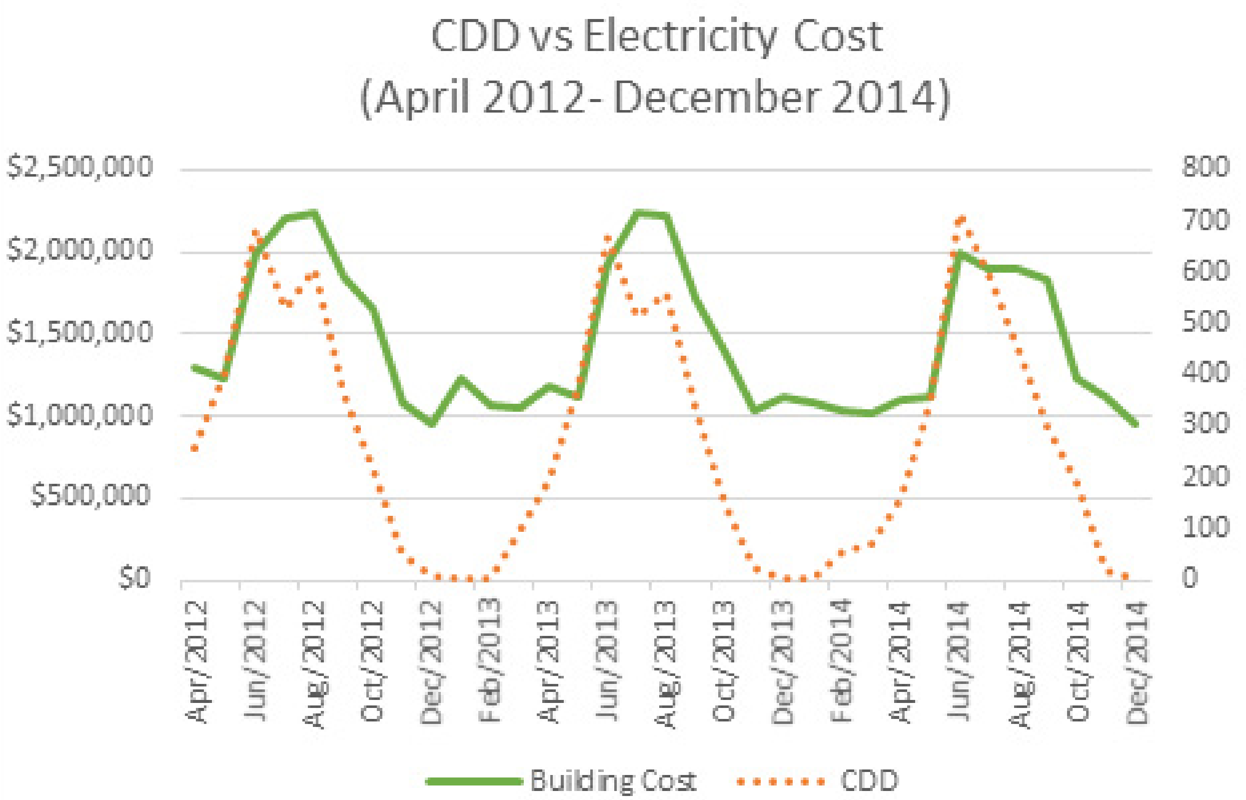

Figure 11 Fort Bliss CDD and Electricity Cost Comparison

The graph here shows the CDD and cost trends, a useful comparison for seasonal weather and to gain an understanding of some of the costs associated for indoor comfort and daily operations. The correlation coefficient of CDD and cost is 0.86, indicating that there is a slight correlation. One possible explanation for a higher correlation between CDD and cost versus CDD and building consumption could be a reflection of higher electricity cost due to peak demand.

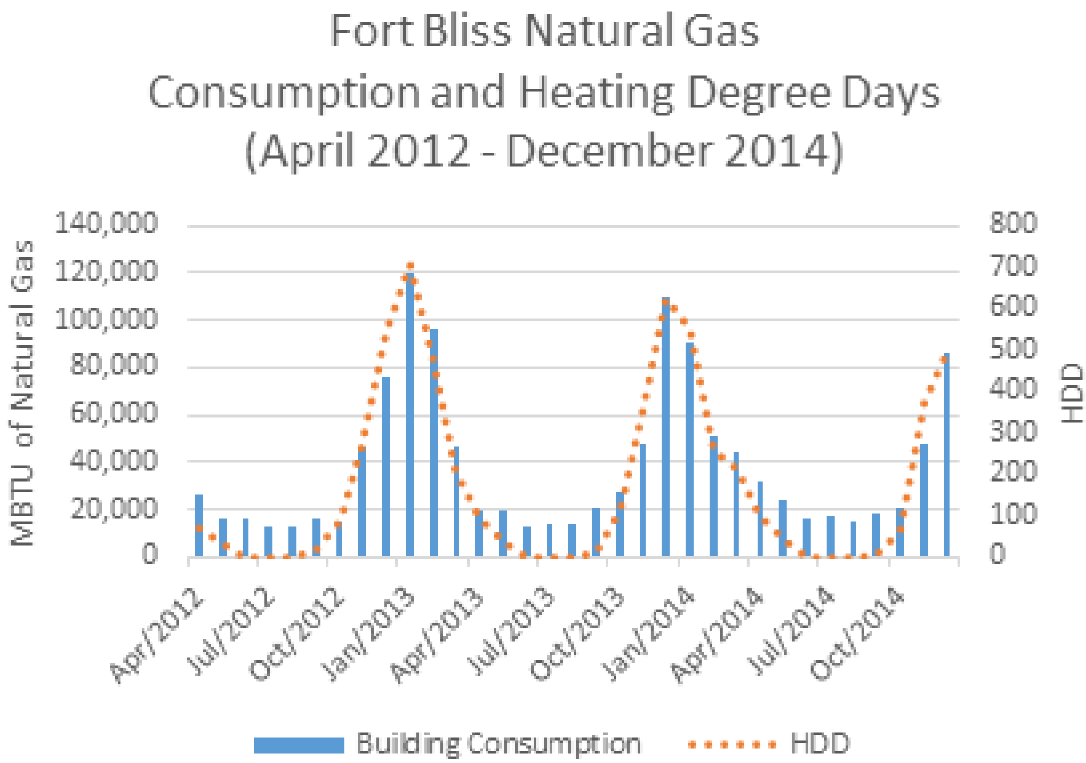

Figure 12 Fort Bliss Natural Gas Consumption and HDD

Fort Bliss, located in El Paso, TX where the average annul low temperature is 51.8 °F (US Climate Data, 2015), has a much lower demand for natural gas. The highest demand is during the winter months from November to February when average monthly temperatures can dip to the 30s. The heating degree days and cost of natural gas have a positive correlation (0.92).

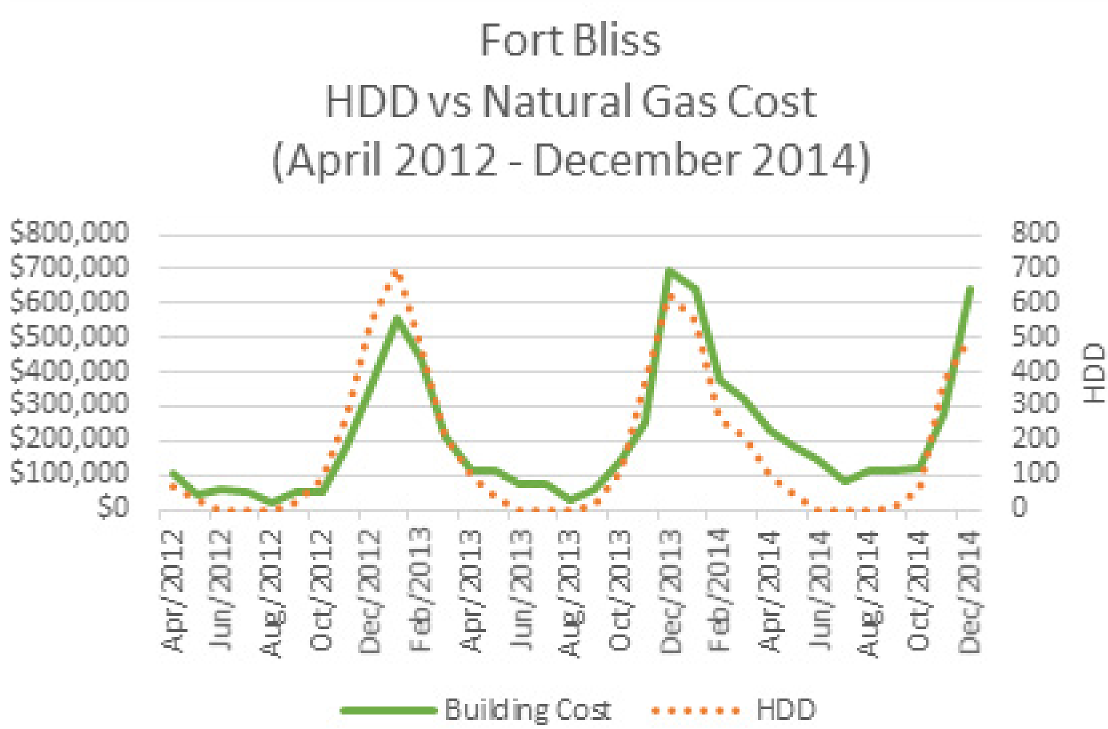

Figure 13 Fort Bliss HDD and Natural Gas Cost Comparison

Challenges

Silo-ed Data

Some of the major challenges in this research were understanding the problem, finding data sources, and developing solutions with available data and keeping the data and analysis must be kept to a simplified process that is understandable and replicable within a few weeks and assuming the person/people in charge of analysis do not have specialized skills in GIS or energy modelling.

Scale of the Problem

One of the major challenges to this research is determining the appropriate scale to analyze the data. For example, if the metric is standardized in an effort to reduce bias, is it safe to assume that installations reflect broader patterns of a nearby city, the county it is in, the state, or a larger region?

Conclusions and Recommendations

Developing goals and benchmarks to track the path of reaching those goals, is a common planning practice, especially in climate and sustainability planning. Using performance metrics for a region, city or even Army installation is a prudent step to ensuring energy goals and federal mandates are met. Additionally, measuring and comparing can provide a healthy competitive atmosphere among stakeholders that encourages long-term behavior change.

The Army already has several methods and databases for collecting utility, renewable energy and sustainable design. The challenge however is developing a specific metric that combines those factors to give an overall understanding and ranking of sustainable and secure energy on installations. This will not only be useful for strategic realignments but to evaluate where investments or improvements can be made.

Building efficiency, renewable energy and energy security are the main areas of focus for the Army. And although there are several different branches and departments that gather and collect energy related data in different ways, it is clear that these three characteristics are imperative for the Army to reach their established goals.

Now that there is a clearer understanding of what data is available and how it can be accessed. Developing a more sophisticated method for quantifying the three main characteristics (building efficiency, renewable energy and energy security) can begin.

Section 1: Environmental Elasticity MVA Attribute

Environmental Elasticity
AS OF: 16 APR 04
1. DEFINITION: Environmental elasticity is the ability of an installation to absorb varying sizes of units based on additional unit loads and the costs of training land, energy, water and wastewater treatment, and solid waste.

2. PURPOSE: Determines the environmental elasticity of an installation, the ability to economically absorb additional units.

3. SOURCE: Installation Military Value Data Call.

4. METHODOLOGY:

a. Background

An assessment of an installation's capacity and cost to provide training land, energy, water and waste treatment/ management resources is a key component of the Army's stationing analysis process and military value analysis. The methodology outlined below assesses the relationships between capacity (as benefits) and the costs for the above resources to be considered in a consistent, comprehensive way.

b. Method

i.The four resources examined are: Training Land, Energy (Electricity and Natural Gas); Water and Wastewater treatment; and Solid Waste. The per soldier costs for each of these resources at existing installations is computed based on existing costing and stationing data. These costs will be used to predict the ability of an installation to absorb additional soldiers until the threshold capacity for that resource is reached. The threshold capacity of a resource is the point where significant new infrastructure investment or other costs would have to be borne to absorb additional soldiers.

ii. The methodology identifies the threshold capacity for both energy and water and wastewater. For training land, other projects underway determine the threshold capacity. For solid waste, it is assumed that off-post disposal is unlimited and there is no threshold capacity limit. For energy, it is assumed that off-installation supply is unlimited but there are threshold capacity restrictions due to limits on distribution for both substations and transmission lines. For water supply and treatment, threshold capacity restrictions may be due to treatment plant size, distribution limits, or permit restrictions.

iii. A linear extrapolation of costs for additional soldiers until the threshold capacity is reached will be assumed since individual contracts will not be examined to determine where increases may be imposed by contract. Once the threshold capacity for energy or water is reached, new cost parameters for soldier absorption would be needed.

c. Steps

i. Identify number of Soldiers (P0) currently stationed at an installation. - numeric provided by TABS. This metric is "loaded" to include people such as Soldiers, civilians, dependents, transients, etc.

ii. Identify total annual costs by installation (from recent FY) for the resource –dollars.

iii. Calculate resource cost per Soldier, by installation at current stationing levels (the cost per Soldier remains the same until the capacity threshold is reached). - $/Soldier. (AS, BS, etc).

iv. Identify peak or highest monthly usage (from recent FY) by installation for the resource – usage metric.

v. Calculate peak resource usage per Soldier by installation –usage metric/Soldier.

vi. Calculate capacity threshold for the resource – in usage terms.

vii. Calculate maximum number of Soldiers, by installation, that can be supported at the resource capacity threshold for energy (EM) and water and wastewater (WM)– numeric.

viii. Calculate total annual costs of each resource to support Soldiers (P0 plus unit of action (UA)) up until capacity threshold. –dollars.

ix. The results of the prior steps will be used by TABS to derive resource elasticities. (To be discussed,).

d. Analytical Matrix The steps produce the inputs for the following matrix which shows:

i. The cost per soldier for each resource (Step iii above).

ii. The total annual costs for current stationing and additional Soldiers (Step viii above).

iii. The threshold capacity in number of soldiers the resource can support (Step vii above).

iv. Where the capacity threshold is exceeded marked by an "X".

5. QUESTIONS THAT DEFINE DATA:

a. Electricity Peak Demand and Total Annual Cost

Question: What was the highest kW demand for electricity on the installation on the peak day during each of the fiscal years: FY01, FY02, and FY03? What was the total annual electric cost in Thousands of Dollars for FY01, FY02, and FY03?

b. Distribution Capacity Rating for Dedicated Substation(s) and Transmission Line(s)

Question: What is the kW capacity rating for each dedicated substation servicing the installation? What is the kW capacity rating for each transmission line from a dedicated substation(s) to the installation?

c. Distribution Capacity Rating and Peak Demand for Non-dedicated Substation(s)

Question: If the installation is serviced by any substation(s) other than a dedicated substation, what is the kW capacity rating of each of the substation(s)? What is the greatest single peak demand from all users (all electric customers, including the installation, served by that substation) over the three-year period FY01 – FY03?

d. Natural Gas: Peak Monthly Usage and Total Annual Cost

Question: What was the peak monthly usage in Thousand Cubic Feet (MCF) for natural gas on the installation during each of the fiscal years: FY01, FY02, and FY03? How many days were in the reported month? What was the total annual natural gas cost in Thousands of Dollars for FY01, FY02, and FY03?

e. Natural Gas Pipeline Capacity

Question: What is the capacity of EACH pipeline servicing the installation in terms of a Thousand Cubic Feet per Day (MCF/Day)?

f. Total Annual Cost of Solid Waste Collection and Disposal

Question: What was the total annual cost for solid waste collection and disposal for each of the fiscal years: FY01, FY02, and FY03?

g. Total Annual Cost of Training Range Maintenance and Repair

Question: What was the total annual cost of Training Range maintenance and repair for fiscal year FY03?

h. Wastewater Treatment: Peak Monthly Usage and Total Annual Operational Cost

Question: What was the peak monthly usage in Million Gallons (MG) of domestic and industrial wastewater treatment on the installation during each of the fiscal years: FY01, FY02, and FY03? How many days were in the reported month? What was the total annual operational cost in Thousands of Dollars for FY01, FY02, and FY03?

i. Potable Water: Peak Monthly Usage and Total Annual Cost

Question: What was the peak monthly usage in Million Gallons (MG) of POTABLE WATER on the installation during each of the fiscal years: FY01, FY02, and FY03? How many days were in the reported month? What was the total annual potable water cost in Thousands of Dollars for FY01, FY02, and FY03?

j. Non-Potable Water: Peak Monthly Usage and Total Annual Cost

Question: What was the peak monthly usage in Million Gallons (MG) of NON-POTABLE WATER on the installation during each of the fiscal years: FY01, FY02, and FY03? How many days were in the reported month? What was the total annual non-potable water cost in Thousands of Dollars for FY01, FY02, and FY03?

6. REFERENCES: ERDC, CERL, AEPI, ESG. DUERS, Installation Master Plans, Installation Status Report (ISR).

7. UNIT OF MEASURE Elasticity, ε, the ability of an installation to economically absorb additional units.

8. EQUATION:

ε =

a. Training Land

i. A0 = Total annual training land cost for current population (from DC2)

ii. A1 = AS * (P0+1UA)

iii. A2 = AS * (P0+2UA)

iv. A3 = AS * (P0+3UA)

b. Energy

i. B0 = Total annual energy costs for electricity and natural gas for current population (from DC2)

ii. B1 = BS * (P0+1UA)

iii. B2 = BS * (P0+2UA)

iv. B3 = BS * (P0+3UA)

c. Water and Wastewater

i. C0 = Total annual costs for potable and non-potable water and domestic and industrial wastewater treatment for current population (from DC2)

ii. C1 = CS * (P0+1UA)

iii. C2 = CS * (P0+2UA)

iv. C3 = CS * (P0+3UA)

d. Solid Waste

i. D0 = Total annual cost for solid waste collection and disposal for current population (from DC2)

ii. D1 = DS * (P0+1UA)

iii. D2 = DS * (P0+2UA)

iv. D3 = DS * (P0+3UA)

e. Capacity Threshold Constraints: For energy and water and wastewater, there are capacity thresholds that constrain the number of Soldiers that can be absorbed by an installation. If a capacity threshold is exceeded when Soldiers are proposed to be added, P0 + 1UA, P0 +2UA, etc, then the energy or water & wastewater costs to support them should NOT be calculated using the above equations.

9. MODEL REQUIREMENTS:

a. Model Input

The primary input data is ε, environmental elasticity.

b. Value Function

i. The value function uses a single equation that measures the returns to scale of the attribute's score and returns the value of an installation's facilities. The curvature of the function is determined by TABS and coordinated by AEPI.

ii. The Maximum value of 10 will be given to the installation with the highest degree of elasticity, ε.

iii. The Minimum value of 0 will be given to the installation with the lowest degree of elasticity, ε.

c.Model Output

i. The value function provides the military value of the installation with regards to the elasticity, ε score.

ii. Scores are normalized on a scale of zero to ten based on value function.

i. This value function shows a linear relationship, which equates to constant returns to scale. The function implies that every additional elasticity increment has the same value as the prior increment.

Section 2: Sample of Transmission Line Vulnerability to Natural Disasters

Installation	Transmission Line Feed	Maximum Total Capacity	Substations Within Base Boundaries	Base Transmission Lines within Wildfire Perimeter (2000 - 2011)	Year of first fire within dataset	Year of last fire within dataset	Minimum Acres	Maximum Acres	Average Acres	Total Acres Affected by Wildfire	Number of Lines along Historic Hurricane Storm Paths	Min_YEAR	Max_YEAR	Maximum Wind Speed (KTS)
(Cooney USARC/AMSA 165SS-G)	2	345	0	0			0	0	0	0	0	0	0	0
Aberdeen Proving Ground	6	460	3	0	-6	-9	-12	-15	-18	-21	-24	0	0	0
Allamanu Military Reservation	1	138	0	0	0	0	0	0	0	0	0	0	0	0
AMSA 161 (G)	1	138	0	0	0	0	0	0	0	0	0	0	0	0
Badger AAP	1	69	0	0			0	0	0	0	0	0	0	0
Barker Dam LTA	10	345	1	5		2011	0	19064	2655	26555	16	0	1995	80
Bell MD	1	138	0	0			0	0	0	0	0	0	0	0
Blue Grass Army Depot	6	161	4	0			0	0	0	0	2	0	2002	20
Camp Atterbury	4	69	2	0			0	0	0	0	0	0	0	0
Camp Dodge Johnston TS	12	690	1	0			0	0	0	0	0	0	0	0
Camp Frank D. Merrill, Dahlonega	5	161	5	0			0	0	0	0	3	0	2004	25
Camp Grafton	2	115	1	0			0	0	0	0	0	0	0	0
Camp Gruber	2	161	0	0			0	0	0	0	2	1979	1979	15
Camp Joseph T Robinson	2	138	0	0			0	0	0	0	2	2005	2005	25
Camp Ripley	6	35	1	0			0	0	0	0	0	0	0	0
Camp Swift	1	138	0	0			0	0	0	0	0	0	0	0
Camp Williams Tomah MTA	1	69	0	0			0	0	0	0	0	0	0	0
Coeur D' Alene Airport LTA	1	115	0	0			0	0	0	0	0	0	0	0
Cornhusker AAP	1	35	0	0			0	0	0	0	0	0	0	0
CTC Camp Dawson-Kingwood	1	138	0	0			0	0	0	0	0	0	0	0
Defense Distribution Region West Shar	2	69	1	0			0	0	0	0	0	0	0	0
Defense Distribution Region West Trac	3	138	1	0			0	0	0	0	0	0	0	0
Defense General Supply Center	2	230	0	0			0	0	0	0	0	0	0	0
Defense Supply Center Columbus	2	138	1	0			0	0	0	0	0	0	0	0
Deseret Chemical Depot	1	46	1	0			0	0	0	0	0	0	0	0
Detroit Arsenal	1	240	0	0			0	0	0	0	1	2008	2008	50
Donnelly Training Area	2	138	2	2	2010	2010	4287	4287	4287	8574	0	0	0	0
Dugway Proving Ground	1	46	1	2	2006	2006	2882	2882	2882	2882	0	0	0	0
Fort A P Hill	1	35	0	0			0	0	0	0	0	0	0	0
Fort Belvoir	4	460	1	0			0	0	0	0	0	0	0	0
Fort Benjamin Harrison	1	138	0	0			0	0	0	0	0	0	0	0
Fort Benning AL	2	115	0	0			0	0	0	0	1	0	2001	20
Fort Benning GA	4	115	2	0			0	0	0	0	0	0	0	0
Fort Bliss	20	345	9	3		2009	0	30182	1509	30182	2	0	2008	20

Section 3: Regional Energy Mix

Data source US Energy Information Administration (http://www.eia.gov/state)

Fort Bliss, Texas

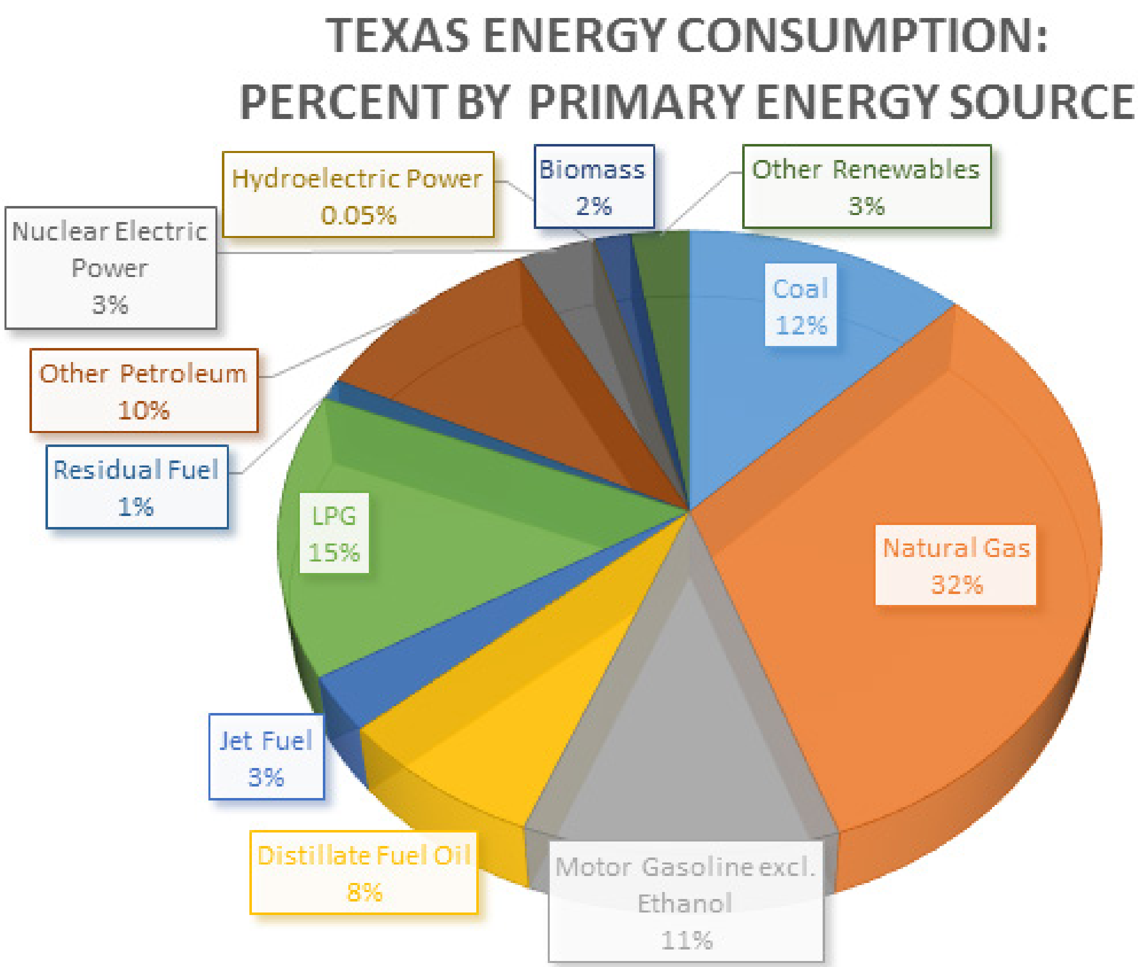

Figure 8 Texas Energy Consumption provides a regional or larger geographic territory for comparison with Fort Bliss, located in El Paso, TX at the border of Texas and New Mexico

- Texas was the leading crude oil-producing state in the nation in 2013
- Texas accounted for about 29% of U.S. marketed natural gas production in 2013, making it the leading natural gas producer among the states.
- Texas leads the nation in wind-powered generation capacity with over 12,000 megawatts; in 2013 Texas generated almost 36 million mWh of electricity from wind energy.
- The average annual electricity cost per Texas household is $1,801, among the highest in the nation; the cost is similar to other warm weather states like Florida, according to EIA's Residential Energy Consumption Survey.
- Ranked fifth highest in energy consumption per capita among the fifty states, with an estimated 471 million BTU per capita.
- Cost of natural gas: $8.64 per thousand cubic feet.
- Cost of electricity: 11.54 cents per kWh

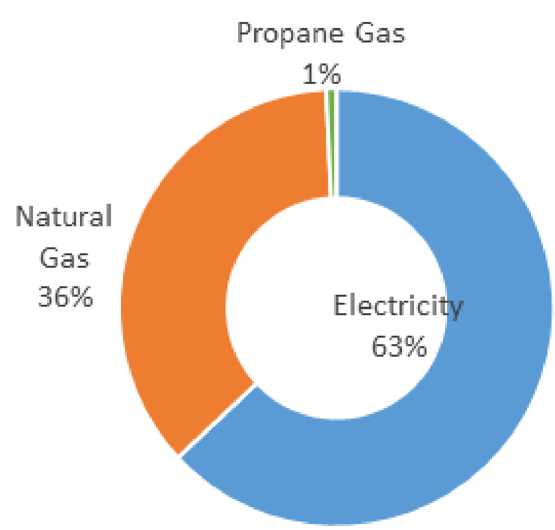

Figure 9 Fort Bliss Energy Consumption

Fort Bragg, North Carolina

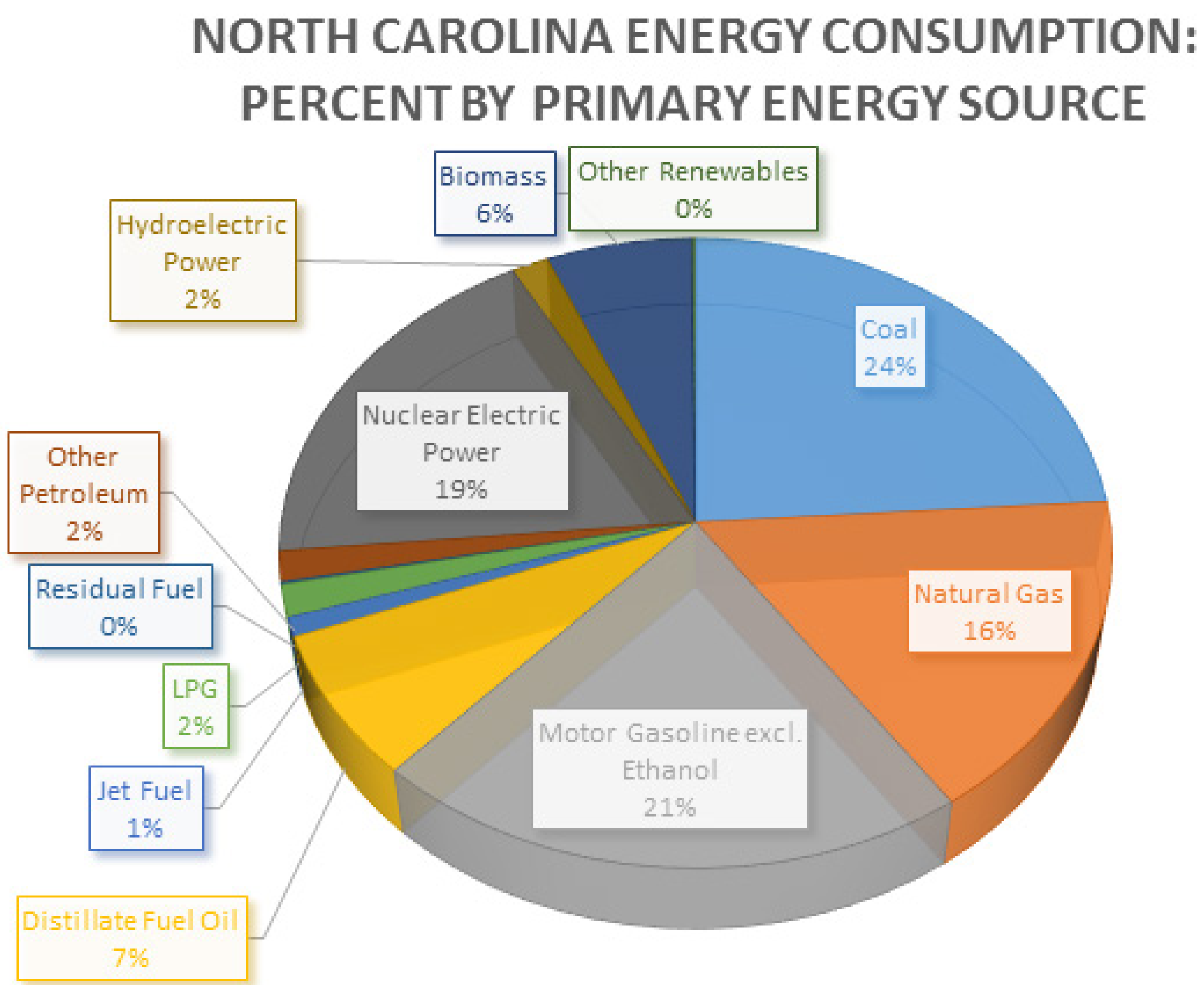

Figure 10 North Carolina State Energy Consumption Mix

- The Dixie Pipeline transports propane from Texas, Louisiana, and Mississippi to customers throughout the Southeast and terminates in Apex, North Carolina, where a terminal and above-ground storage tanks are located.
- Of the 813 public and private-access biodiesel fueling stations nationwide, over 16% are in North Carolina.
- North Carolina ranked sixth in the nation in net electricity generation from nuclear power in 2013, producing 5.1% of the nation's total.
- Over one-third of North Carolina's net electricity generation—38% in 2013—came from coal shipped by rail and truck, primarily from West Virginia and Kentucky.
- In 2013, 7.5% of North Carolina's net electricity generation came from renewable energy resources, almost all of it from conventional hydroelectric power and biomass.
- Total energy per capita: 255 million (ranked 38th in the US).

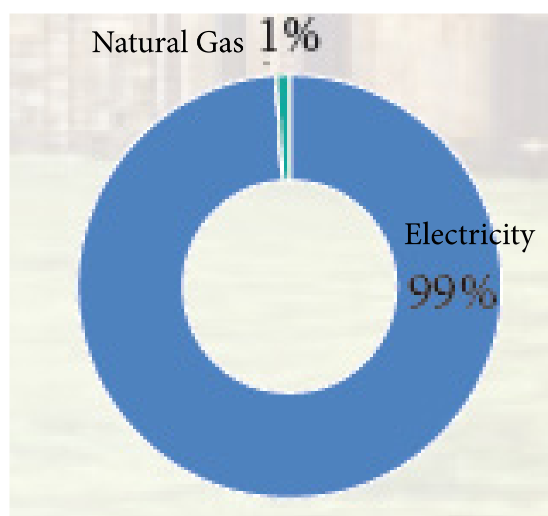

Figure 11 Fort Bragg Energy Consumption

Fort Drum, New York

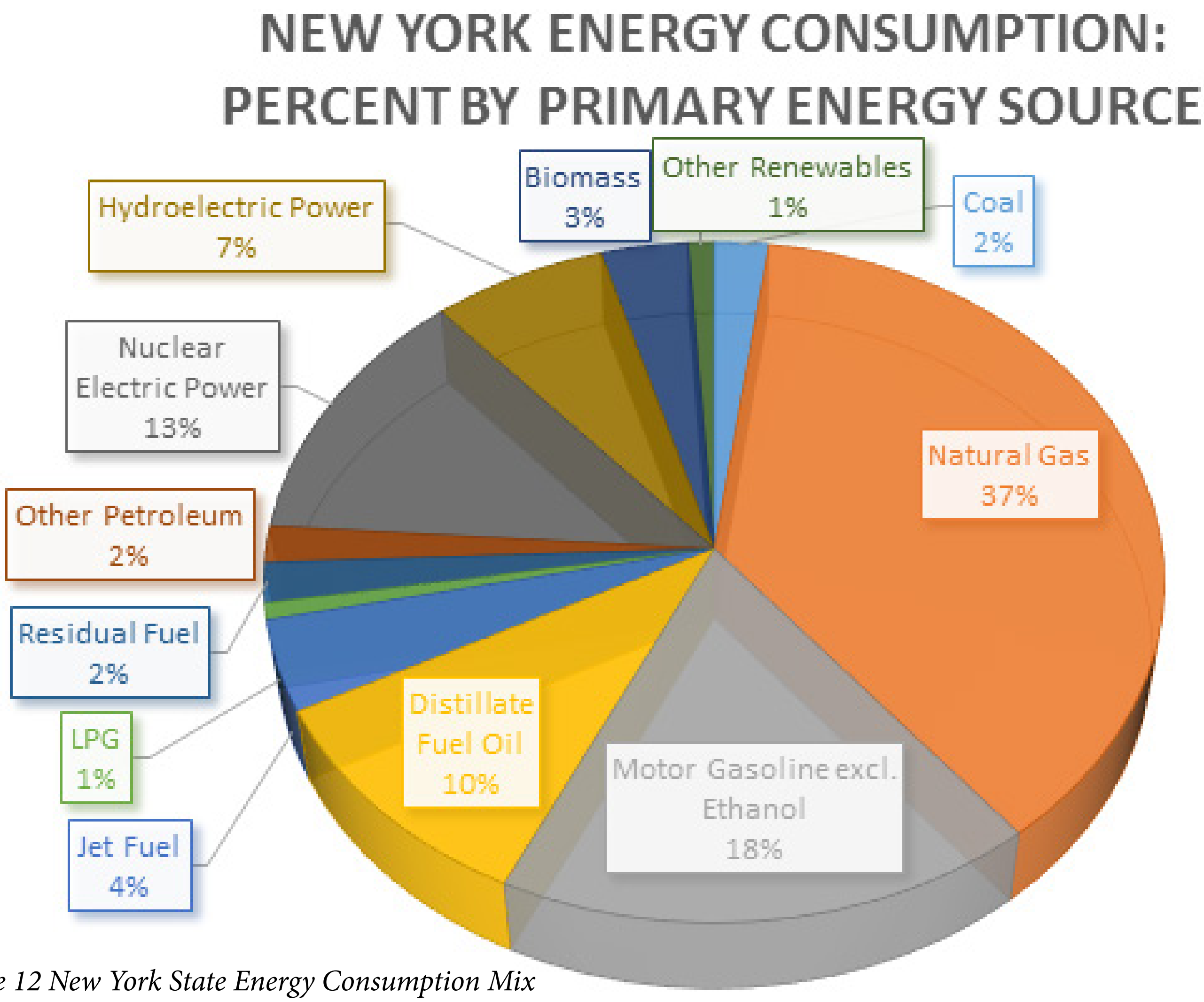

Figure 12 New York State Energy Consumption Mix

- In 2011, New York was the eighth largest energy consumer among the 50 states, but, due in part to its widely used mass transportation systems, it had the second lowest energy consumption per capita after Rhode Island.
- The Marcellus shale, which underlies southwestern New York and extends southward through Pennsylvania, West Virginia, and Ohio, is estimated to hold at least 141 trillion cubic feet in technically recoverable natural gas.
- The 2,353-megawatt Robert Moses Niagara hydroelectric power plant is the fourth largest hydroelectric power plant in the United States and, in 2013, New York produced more hydroelectric power than any other state east of the Rocky Mountains.
- New York's Renewable Portfolio Standard requires that 30% of electricity come from renewable energy resources by 2015; in 2013, 23% of the state's electricity generation came from renewable energy resources.
- In 2013, New York had the fourth highest average electricity prices in the United States.

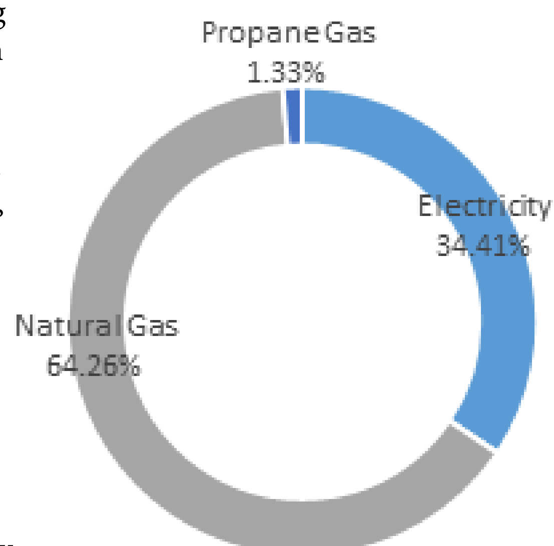

Figure 13 Fort Drum Annual Energy Consumption

Fort Riley, Kansas

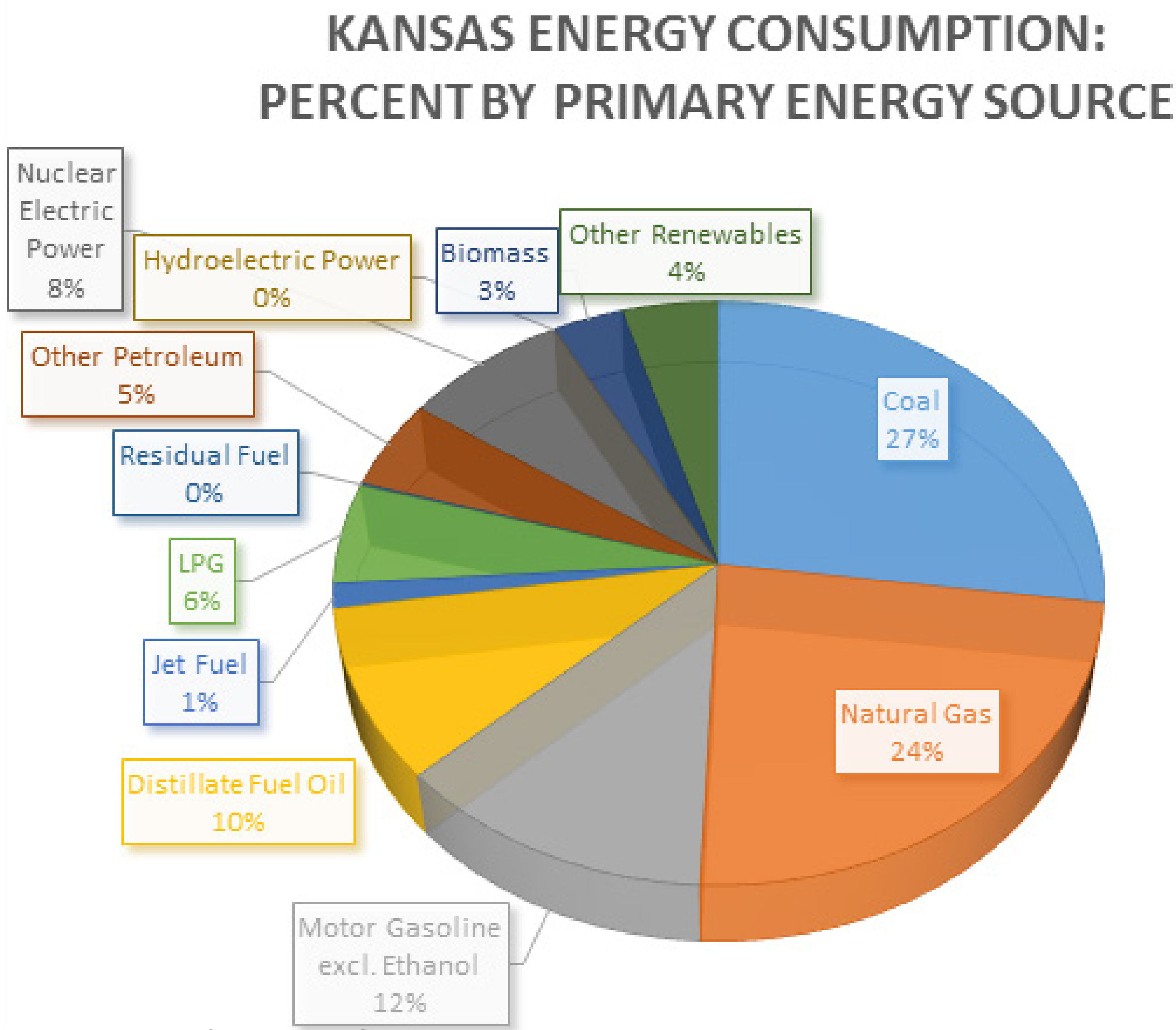

Figure 14 Kansas State Energy Consumption Mix

- In 2013, Kansas ranked 10th in crude oil production among the 50 states, excluding the federal offshore areas.
- The Hugoton Gas Area, which contains one of the top-producing natural gas fields in the United States, is located in southwestern Kansas, as well as in parts of the Texas and Oklahoma panhandles.
- The Mid-Continent Center, located in south central Kansas, is a key natural gas supply hub that takes production from several states in the region and pipes it east to major consumption markets.
- Electric utilities in Kansas provided 82% of the state's net electricity generation in 2013; 61% of net electricity generation came from coal-fired electric power plants.
- In 2013, 19% of net electricity generation in Kansas came from wind energy.

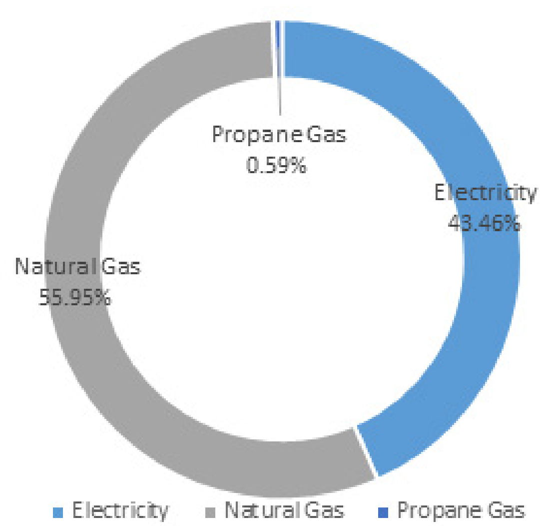

Figure 15 Fort Riley Energy Consumption

Fort Wainwright, Alaska

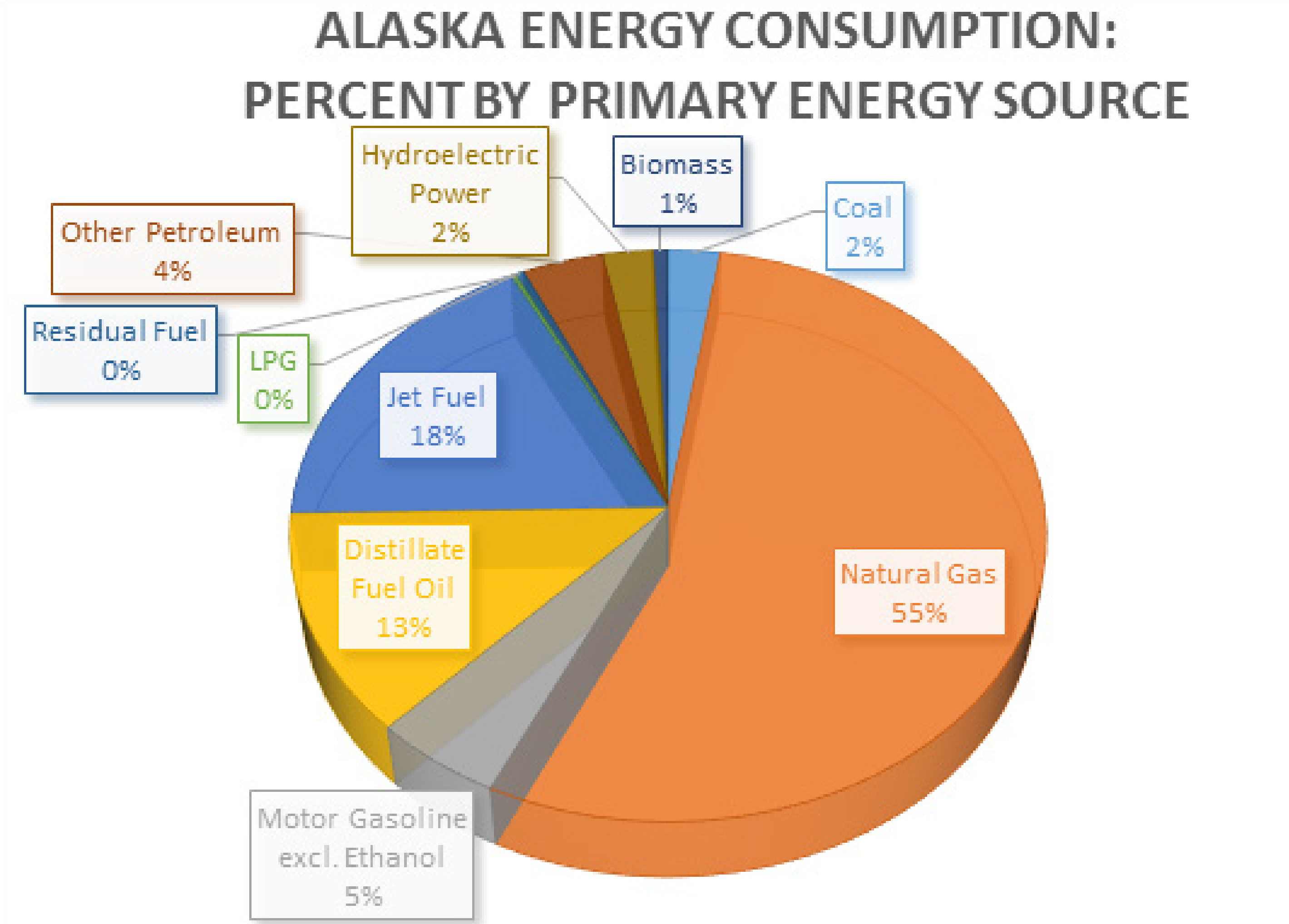

Figure 16 Alaska State Energy Consumption Mix

- Alaska's electricity infrastructure differs from that of the lower 48 states in that most consumers are not linked to large interconnected grids through transmission and distribution lines; rural communities in Alaska rely primarily on diesel electric generators for power.

- Alaska ranked second in the United States in 2013 in the share of its electricity that is generated from petroleum liquids.

- Alaska was one of only a handful of states in 2013 generating electricity from geothermal energy sources.

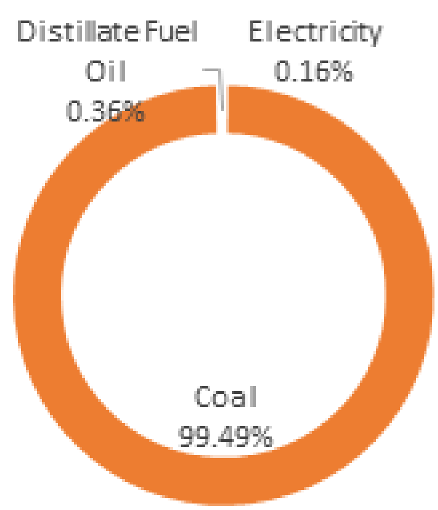

Figure 17 Fort Wainwright Energy Consumption

Joint Base Lewis-McChord, Washington

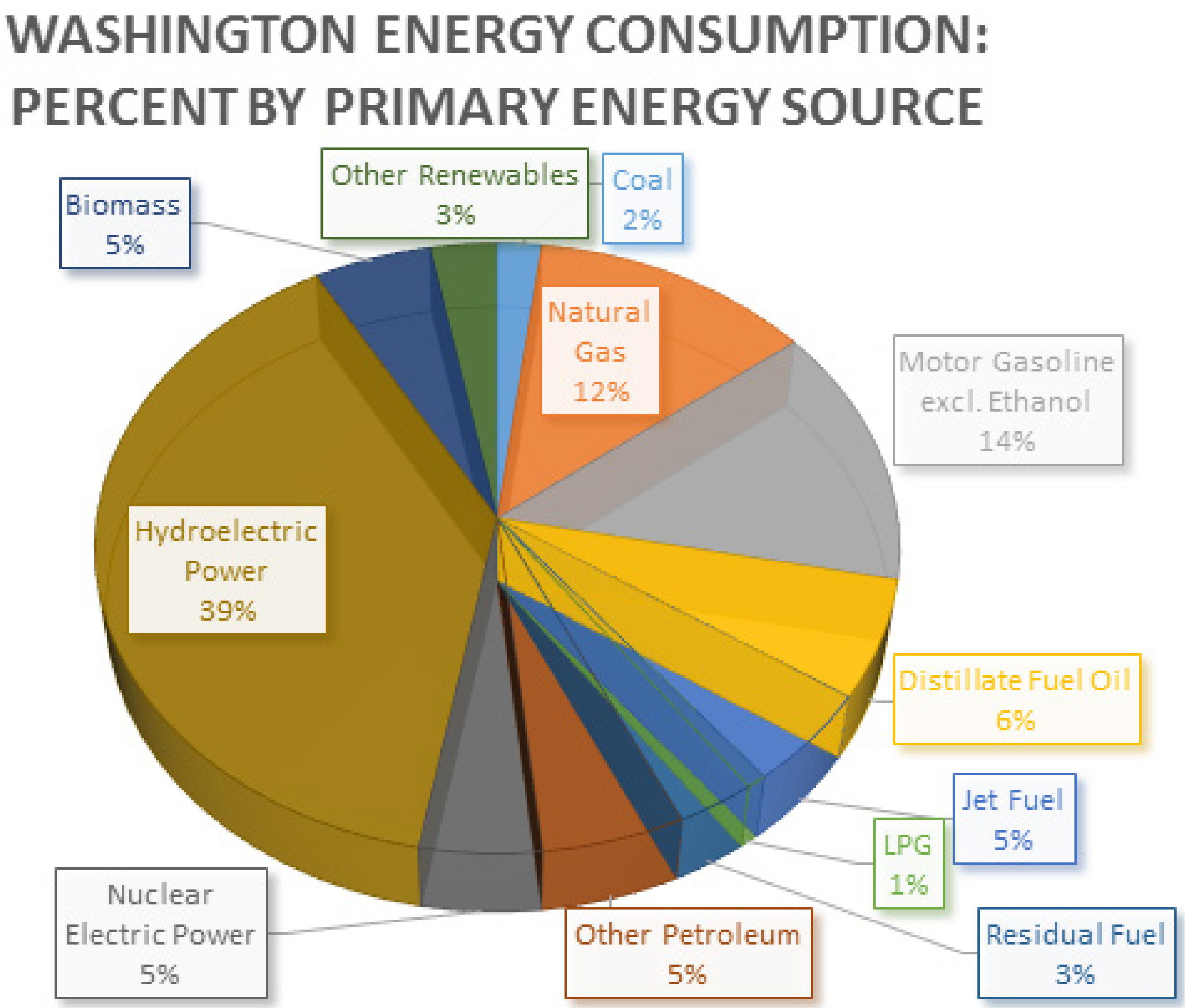

Figure 18 Washington State Energy Consumption Mix

- The Grand Coulee Dam on Washington's Columbia River is the largest hydroelectric power producer in the United States, with a total generating capacity of 6,809 megawatts.
- In 2013, Washington was the leading producer of electricity from hydroelectric sources and produced 29% of the nation's net hydroelectricity generation.
- Although not a crude oil-producing state, Washington ranked fifth in the nation in crude oil-refining capacity as of January 2014.
- Washington ranked 10th in the nation in net generation of electricity from wind energy in 2013.
- In 2013, Washington had the lowest residential electricity prices in the nation and the lowest combined electricity price across all sectors.

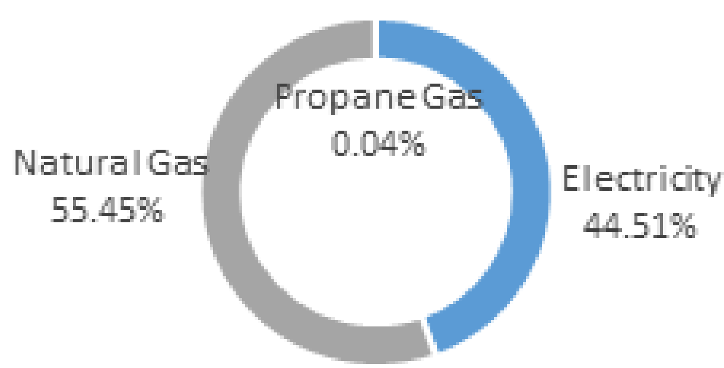

Figure 19 Joint Base Lewis-McChord Energy Consumption

USAG Hawaii/Schofield Barracks

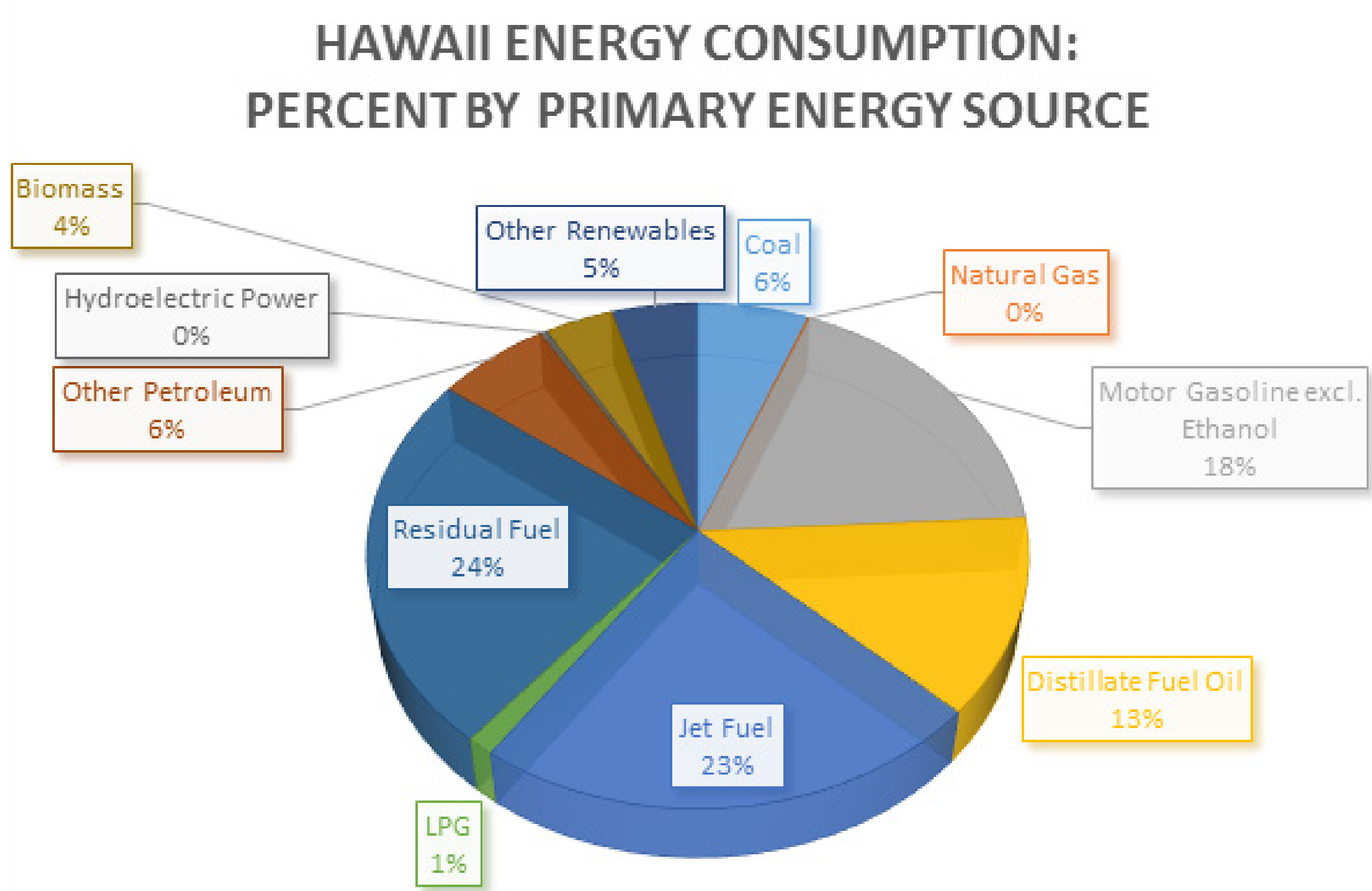

Figure 20 Hawaii Energy Consumption Mix

- With its mild tropical climate, Hawaii had the fourth lowest per capita energy use in the nation in 2012. The transportation sector led Hawaiian energy demand in 2012, due in large part to heavy commercial and military aviation fuel use.
- In 2012, Hawaii imported 93% of the energy it consumed and, in 2013, the state had the highest electricity prices in the nation.
- Hawaii has the world's largest commercial electricity generator fueled exclusively with biofuels; the state's energy plan aims for an agricultural biofuels industry that, by 2025, can provide 350 million gallons of biofuels.
- Hawaii is one of eight states with installed geothermal capacity; in 2013, 23% of its renewable net electricity generation came from geothermal energy.
- Hawaii's utility-scale electricity generation from solar energy increased nearly six-fold in 2013.

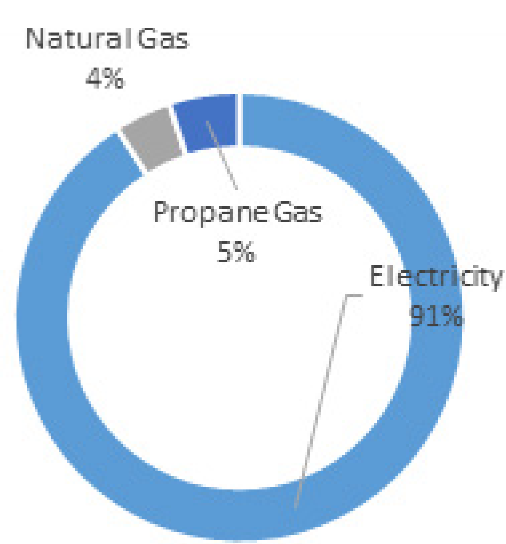

Figure 21 USAG Hawaii Energy Consumption

Works Cited

Birkmann, J., Garschagen, M., Kraas, F., & Quang, N. 2010. Adaptive urban governance: new challenges for the second generation of urban adaptation strategies to climate change. Sustainability Science, 5(2), 185-206.

Booth, Samuel, John Barnett, Kari Burman, Josh Hambrick, and Robert Westby. 2010. Net Zero Energy Military Installations: A Guide to Assessment and Planning. In Technical Report NREL/TP-7A2-78876.

Brown, Casey, Scott Steinschneider, Sungwook Wi, John Weatherly, Michael Case, Timothy Hayden, Linda Mearns, Melissa Bukovsky, and Rachel McCrary. 2013. Decision-Scaling: A decision framework for DoD climate risk assessment and adaptation planning. Interim Report, Version 1.

Brown, Lester. 2011. World on the Edge: How to Prevent Environmental and Economic Collapse. Earth Policy Institute, 8: 99-115.

CAA. 2014. Welcome to CAA. http://www.caa.army.mil/

Governmental Accounting Service (GAO). 2013. Military Bases: Opportunities exist to improve future base realignment and closure rounds. Report to Congressional Committees.

Johnson Controls. 2015. Energy Efficiency & Sustainability. Building Efficiency – Building Technologies & Services. http://www.johnsoncontrols.com/content/us/en/products/building_efficiency/service-and-solutions/energy_efficiency.html

Lopez, Anthony, Billy Roberts, Donna Heimiller, Nate Blair, and Gian Porro. 2012. U.S. Renewable Energy Technical Potentials: A GIS-Based Analysis. Technical Report NREL/TP-6A20-51946

Office of the Deputy Under Secretary of Defense (Installations and Environment). 2013. Department of Defense Annual Energy Management Report: Fiscal Year 2012.

Ruth, M., & Coelho, D. (2007). Understanding and managing the complexity of urban systems under climate change. Climate Policy, 7(4), 317-336.

The Army Senior Energy Council and the Office of the Deputy Assistant Secretary of the Army for Energy and Partnerships. (2009). Army Energy Security Implementation Strategy.

US DOD. 2013. News Release. Army Announces Force Structure and Stationing Decisions. http://www.defense.gov/releases/release.aspx?releaseid=16114

U.S. Climate Data. 2015. http://www.usclimatedata.com/climate/el-paso/texas/united-states/ustx0413